

BS EN 206:2013

Incorporating corrigendum May 2014



BSI Standards Publication

Concrete — Specification, performance, production and conformity

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National foreword

This British Standard is the UK implementation of EN 206:2013. It supersedes BS EN 206-1:2000 and BS EN 206-9:2010 which are withdrawn.

The CEN Correction Notice 12 March 2014 provided a revised English language text, incorporating the following editorial corrections:

- In the Foreword, add after the 3rd paragraph,
“Based on a CEN/BT Decision (DECISION BT 42/2013) EN 12620:2013 was withdrawn. Therefore, this document has been aligned with the specifications given in EN 12620:2002+A1:2008. As soon as CEN/TC 154 publishes a new version of EN 12620, CEN/TC 104 intends to amend EN 206.”
- In Clause 2, replace “EN 12620:2013” with “EN 12620:2002+A1:2008”.
- In 3.1, Terms and definitions, delete in 3.1.2.5, 3.1.2.6, 3.1.2.7, “[SOURCE: EN 12620:2013, 3.x]”.
- In 5.1.3, (2), delete “listed in EN 12620 with identified history of use,”.
- In 5.1.3, delete the last paragraph (3).
- In Table E.1, 2nd column, replace “EN 12620:2013” with “EN 12620:2002+A1:2008” and update all cross references.
- In Table E.1, 3rd column, 4th row, delete “≤”.
- In Table E.1, 3rd column, 5th row, replace “SZ₃₈” with “SZ₃₂”.
- In Table E.1, 3rd column, 9th row, replace “S₁” with “1 % by mass” and “S₂” with “2 % by mass”.
- In E.3, note after Table E.2, replace “EN 12620:2013”, C.3” with “EN 12620:2002+A1:2008, G.3.2”.
- In Table E.3, 2nd column, replace “EN 12620:2013” with “EN 12620:2002+A1:2008” and update all cross references.
- In Table E.3, 4th column, 4th row, replace “SZ₃₈” with “SZ₃₂”.
- In Table E.3, 4th column, 10th row, replace “≤ SS_{0,7}” with “SS_{0,2}”.
- In Annex M, row 5.1.3, last column, replace “(1), (2) and (3)” with “(1) and (2)”.

It is intended that this British Standard be used in conjunction with the complementary standards BS 8500-1 and BS 8500-2, which give national provisions where they are permitted in EN 206:2013. Additionally, the UK committee draws particular attention to subclause 10.1, which recommends “the inspection and certification of the production control by accredited inspection and certification bodies”.

The UK participation in its preparation was entrusted by Technical Committee B/517, Concrete to Subcommittee B/517/1, Concrete production and testing.

A list of organizations represented on this subcommittee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Compliance with a British Standard cannot confer immunity from legal obligations.

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Amendments/corrigenda issued since publication

| Date | Text affected |
|-------------|---|
| 31 May 2014 | Implementation of CEN correction notice 12 March 2014. National foreword updated. |

English Version

Concrete - Specification, performance, production and
conformity

Béton - Spécification, performances, production et
conformité

Beton - Festlegung, Eigenschaften, Herstellung und
Konformität

This European Standard was approved by CEN on 28 September 2013.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

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Foreword

This document (EN 206:2013) has been prepared by Technical Committee CEN/TC 104 “Concrete and related products”, the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by June 2014 and conflicting national standards shall be withdrawn at the latest by June 2014.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

Based on a CEN/BT Decision (DECISION BT 42/2013) EN 12620:2013 was withdrawn. Therefore, this document has been aligned with the specifications given in EN 12620:2002+A1:2008. As soon as CEN/TC 154 publishes a new version of EN 12620, CEN/TC 104 intends to amend EN 206.

This document supersedes EN 206-1:2000 and EN 206-9:2010.

In particular, the following main items were subject to revision when preparing this European Standard:

- a) adding application rules for fibre concrete and concrete with recycled aggregates;
- b) revising k -value concept for fly ash and silica fume and adding new rules for ground granulated blast furnace slag;
- c) introduction of principles for the performance concepts for the use of additions, e.g. equivalent concrete performance concept and equivalent performance of combinations concept;
- d) revising and adding new concepts for the conformity assessment;
- e) including EN 206-9 “Additional rules for self-compacting concrete (SCC)”;
- f) including additional requirements for concrete for special geotechnical works (Annex D).

NOTE Annex D was jointly prepared by CEN/TC 104 and CEN/TC 288.

Figure 1 illustrates the relationships between EN 206 and standards for design and execution, standards for constituents and test standards.

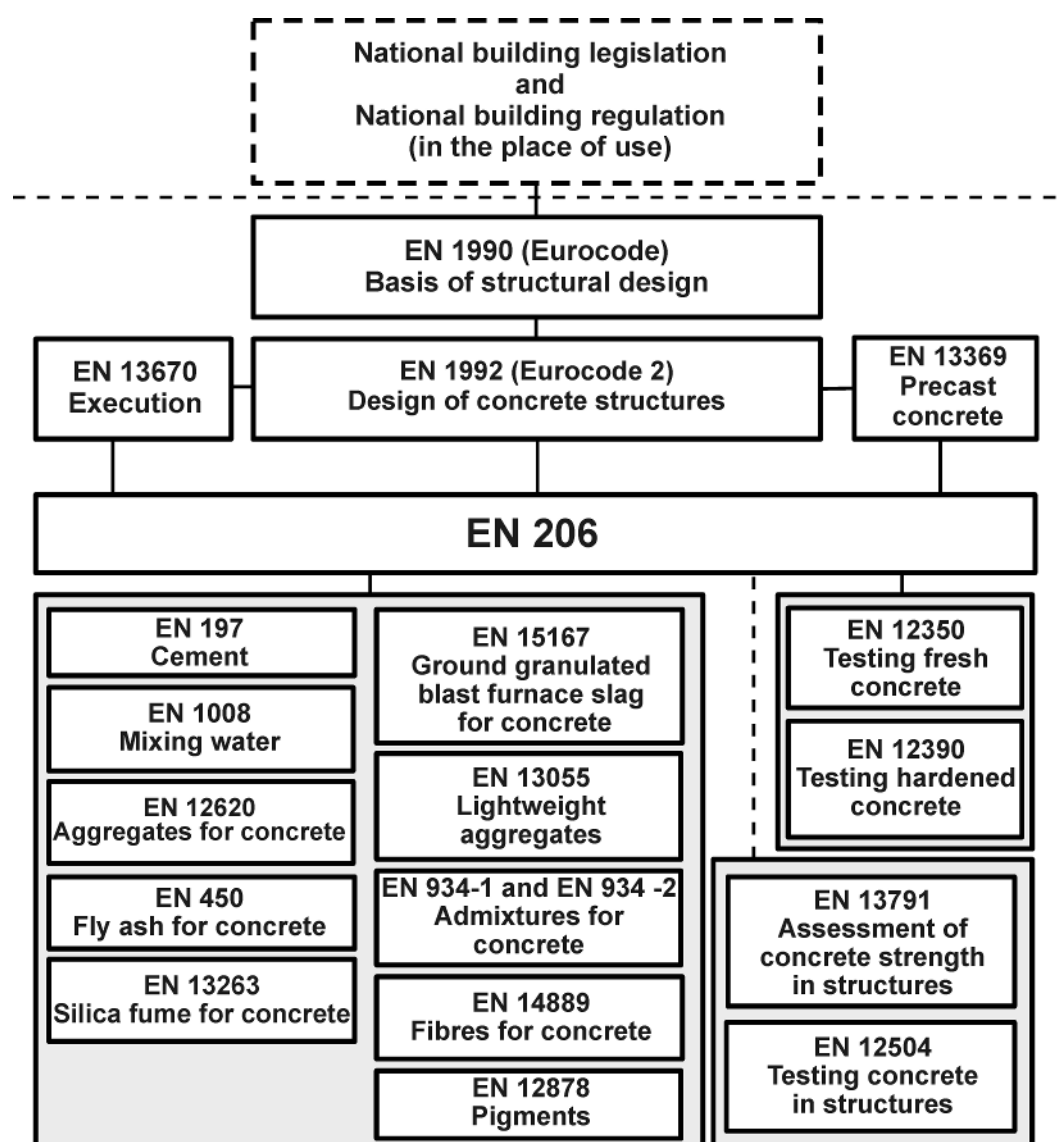


Figure 1 — Relationships between EN 206 and standards for design and execution, standards for constituents and test standards

According to the CEN/CENELEC Internal Regulations, the national standards organisations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Introduction

This European Standard will be applied under different climatic and geographical conditions, different levels of protection and under different, well established, regional traditions and experience. Classes for concrete properties have been introduced to cover these situations. Where such general solutions were not possible, the relevant clauses contain permission for the application of provisions valid in the place of use of the concrete.

This European Standard incorporates rules for the use of constituents that are covered by European Standards. Constituents not covered by European Standards may be used in accordance with provisions valid in the place of use of the concrete.

If the concrete is in conformity with the limiting values, the concrete in the structure is deemed to satisfy the durability requirements for the intended use in the specific environmental condition, provided:

- the appropriate exposure classes were selected;
- the concrete has the minimum cover to reinforcement in accordance with the relevant design standard required for the specific environmental condition, e.g. EN 1992-1-1;
- the concrete is properly placed, compacted and cured, e.g. in accordance with EN 13670 or other relevant standards;
- the appropriate maintenance is applied during the working life.

Performance based concepts as alternatives to the concept of limiting values are under development.

Concrete conforming to this European Standard may be assumed to satisfy the basic requirements for materials to be used in all three Execution Classes as defined in EN 13670.

This European Standard defines tasks for the specifier, producer and user. For example, the specifier is responsible for the specification of concrete, Clause 6, and the producer is responsible for conformity and production control, Clauses 8 and 9. The user is responsible for placing the concrete in the structure. In practice there may be several different parties specifying requirements at various stages of the design and construction process, e.g. the client, the designer, the contractor, the concreting sub-contractor. Each is responsible for passing the specified requirements, together with any additional requirements, to the next party in the chain until they reach the producer. In the terms of this European Standard, this final compilation is known as the “specification of concrete”. Conversely, the specifier, producer and user may be the same party (e.g. a precast concrete manufacturer or a contractor doing design and build). In the case of ready-mixed concrete, the purchaser of the fresh concrete is the specifier who gives the specification of concrete to the producer.

This European Standard also covers the necessary exchange of information between the different parties. Contractual matters are not addressed. Where responsibilities are given for parties involved, these are technical responsibilities.

Notes and footnotes in tables of this standard are normative unless stated otherwise; other notes and footnotes are informative.

Further explanations and guidance on the application of this standard are given in other documents, such as CEN Technical Reports.

1 Scope

(1) This European Standard applies to concrete for structures cast in situ, precast structures, and structural precast products for buildings and civil engineering structures.

(2) The concrete under this European Standard can be:

- normal-weight, heavy-weight and light-weight;
- mixed on site, ready-mixed or produced in a plant for precast concrete products;
- compacted or self-compacting to retain no appreciable amount of entrapped air other than entrained air.

(3) This standard specifies requirements for:

- the constituents of concrete;
- the properties of fresh and hardened concrete and their verification;
- the limitations for concrete composition;
- the specification of concrete;
- the delivery of fresh concrete;
- the production control procedures;
- the conformity criteria and evaluation of conformity.

(4) Other European Standards for specific products e.g. precast products or for processes within the field of the scope of this standard may require or permit deviations.

(5) Additional or different requirements may be given for specific applications in other European Standards, for example:

- concrete to be used in roads and other trafficked areas (e.g. concrete pavements according to EN 13877-1);
- special technologies (e.g. sprayed concrete according to EN 14487).

(6) Supplementing requirements or different testing procedures may be specified for specific types of concrete and applications, for example:

- concrete for massive structures (e.g. dams);
- dry mixed concrete;
- concrete with a D_{\max} of 4 mm or less (mortar);
- self-compacting concretes (SCC) containing lightweight or heavy-weight aggregates or fibres;
- concrete with open structure (e. g. pervious concrete for drainage).

(7) This standard does not apply to:

- aerated concrete;
- foamed concrete;
- concrete with density less than 800 kg/m³;
- refractory concrete.

(8) This standard does not cover health and safety requirements for the protection of workers during production and delivery of concrete.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 196-2, *Methods of testing cement — Part 2: Chemical analysis of cement*

EN 197-1, *Cement — Part 1: Composition, specifications and conformity criteria for common cements*

EN 450-1, *Fly ash for concrete — Part 1: Definition, specifications and conformity criteria*

EN 934-1:2008, *Admixtures for concrete, mortar and grout — Part 1: Common requirements*

EN 934-2, *Admixtures for concrete, mortar and grout — Part 2: Concrete admixtures — Definitions, requirements, conformity, marking and labelling*

EN 1008, *Mixing water for concrete — Specification for sampling, testing and assessing the suitability of water, including water recovered from processes in the concrete industry, as mixing water for concrete*

EN 1097-3, *Tests for mechanical and physical properties of aggregates — Part 3: Determination of loose bulk density and voids*

EN 1097-6:2013, *Tests for mechanical and physical properties of aggregates — Part 6: Determination of particle density and water absorption*

EN 1536, *Execution of special geotechnical work — Bored piles*

EN 1538, *Execution of special geotechnical work — Diaphragm walls*

EN 12350-1, *Testing fresh concrete — Part 1: Sampling*

EN 12350-2, *Testing fresh concrete — Part 2: Slump-test*

EN 12350-4, *Testing fresh concrete — Part 4: Degree of compactability*

EN 12350-5, *Testing fresh concrete — Part 5: Flow table test*

EN 12350-6, *Testing fresh concrete — Part 6: Density*

EN 12350-7, *Testing fresh concrete — Part 7: Air content — Pressure methods*

EN 12350-8, *Testing fresh concrete — Part 8: Self-compacting concrete — Slump-flow test*

EN 12350-9, *Testing fresh concrete — Part 9: Self-compacting concrete — V-funnel test*

- EN 12350-10, *Testing fresh concrete — Part 10: Self-compacting concrete — L box test*
- EN 12350-11, *Testing fresh concrete — Part 11: Self-compacting concrete — Sieve segregation test*
- EN 12350-12, *Testing fresh concrete — Part 12: Self-compacting concrete — J-ring test*
- EN 12390-1, *Testing hardened concrete — Part 1: Shape, dimensions and other requirements for specimens and moulds*
- EN 12390-2, *Testing hardened concrete — Part 2: Making and curing specimens for strength tests*
- EN 12390-3, *Testing hardened concrete — Part 3: Compressive strength of test specimens*
- EN 12390-6, *Testing hardened concrete — Part 6: Tensile splitting strength of test specimens*
- EN 12390-7, *Testing hardened concrete — Part 7: Density of hardened concrete*
- EN 12620:2002+A1:2008, *Aggregates for concrete*
- EN 12699, *Execution of special geotechnical work — Displacement piles*
- EN 12878, *Pigments for the colouring of building materials based on cement and/or lime — Specifications and methods of test*
- prEN 13055, *Lightweight aggregates for concrete, mortar, grout, bituminous mixtures, surface treatments and for unbound and bound applications*
- EN 13263-1, *Silica fume for concrete — Part 1: Definitions, requirements and conformity criteria*
- EN 13577, *Chemical attack on concrete — Determination of aggressive carbon dioxide content in water*
- EN 14199, *Execution of special geotechnical works — Micropiles*
- EN 14216, *Cement — Composition, specifications and conformity criteria for very low heat special cements*
- EN 14488-7, *Testing sprayed concrete — Part 7: Fibre content of fibre reinforced concrete*
- EN 14721, *Test method for metallic fibre concrete — Measuring the fibre content in fresh and hardened concrete*
- EN 14889-1:2006, *Fibres for concrete — Part 1: Steel fibres – Definitions, specifications and conformity*
- EN 14889-2:2006, *Fibres for concrete — Part 2: Polymer fibres – Definitions, specifications and conformity*
- EN 15167-1, *Ground granulated blast furnace slag for use in concrete, mortar and grout — Part 1: Definitions, specifications and conformity criteria*
- prEN 16502, *Test method for the determination of the degree of soil acidity according to Baumann-Gully*
- EN ISO 7980, *Water quality — Determination of calcium and magnesium — Atomic absorption spectrometric method (ISO 7980)*
- ISO 4316, *Surface active agents — Determination of pH of aqueous solutions — Potentiometric method*
- ISO 7150-1, *Water quality — Determination of ammonium — Part 1: Manual spectrometric method*

ASTM C 173, *Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method*

3 Terms, definitions, symbols and abbreviations

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1.1 General

3.1.1.1

concrete

fr: béton

de: Beton

material formed by mixing cement, coarse and fine aggregate and water, with or without the incorporation of admixtures, additions or fibres, which develops its properties by hydration

3.1.1.2

concrete family

fr: famille de béton

de: Betonfamilie

group of concrete compositions for which a reliable relationship between relevant properties is established and documented

3.1.1.3

delivery

fr: livraison

de: Lieferung

process of handing over the fresh concrete by the producer

3.1.1.4

designed concrete

fr: béton à propriétés spécifiées

de: Beton nach Eigenschaften

concrete for which the required properties and additional characteristics if any are specified to the producer who is responsible for providing a concrete conforming to the required properties and additional characteristics

3.1.1.5

design working life

fr: durée de vie de projet

de: Bemessungslebensdauer

assumed period for which a structure or a part of it is to be used for its intended purpose with anticipated maintenance but without major repair being necessary

3.1.1.6

document

fr: document

de: Dokument

information and its supporting medium, which can be paper, magnetic, electronic or optical computer disc, photograph or reference sample or a combination thereof

3.1.1.7

environmental actions

fr: actions dues à l'environnement

de: Umwelteinflüsse

those chemical and physical actions to which the concrete is exposed and which result in effects on the concrete or reinforcement or embedded metal that are not considered as loads in structural design

3.1.1.8

precast element

fr: élément préfabriqué

de: Fertigteil

concrete element cast and cured in a place other than the final location of use (factory produced or site manufactured)

3.1.1.9

precast product

fr: produit préfabriqué

de: Fertigteil

precast element manufactured in compliance with the relevant European product standard

3.1.1.10

prescribed concrete

fr: béton à composition prescrite

de: Beton nach Zusammensetzung

concrete for which the composition of the concrete and the constituent materials to be used are specified to the producer who is responsible for providing a concrete with the specified composition

3.1.1.11

producer

fr: producteur

de: Hersteller

person or body producing fresh concrete

3.1.1.12

provisions valid in the place of use

fr: dispositions en vigueur sur le lieu d'utilisation du béton

de: am Ort der Verwendung geltende Regeln

national provisions given in a National Foreword or National Annex to this European Standard, or in a complementary national standard to this European Standard applicable in the place of use of the concrete

3.1.1.13

ready-mixed concrete

fr: béton prêt à l'emploi

de: Transportbeton

concrete delivered in a fresh state by a person or body who is not the user; in the sense of this standard it is also:

- concrete produced off site by the user;
- concrete produced on site, but not by the user

3.1.1.14

self-compacting concrete (SCC)

fr: béton auto-plaçant

de: selbstverdichtender Beton

concrete that is able to flow and compact under its own weight, fill the formwork with its reinforcement, ducts, boxouts etc., whilst maintaining homogeneity

3.1.1.15

site-mixed concrete

fr: béton de chantier

de: Baustellenbeton

concrete produced on the construction site by the user of the concrete for his own use

3.1.1.16

site (construction site)

fr: chantier (chantier de construction)

de: Baustelle

area where the construction work is undertaken

3.1.1.17

specification of concrete

fr: spécification du béton

de: Festlegung

final compilation of documented technical requirements given to the producer in terms of performance or composition

3.1.1.18

specifier

fr: prescripteur

de: Verfasser der Festlegung

person or body establishing the specification for fresh and hardened concrete

3.1.1.19

standardized prescribed concrete

fr: béton à composition prescrite dans une norme

de: Standardbeton

prescribed concrete for which the composition is given in a standard valid in the place of use of the concrete

3.1.1.20

user

fr: utilisateur

de: Verwender

person or body using fresh concrete in the execution of a construction or an element

3.1.2 Constituents

3.1.2.1

addition

fr: addition

de: Betonzusatzstoff

finely-divided-inorganic constituent used in concrete in order to improve certain properties or to achieve special properties

3.1.2.2

type I addition

fr: addition de type I

de: Typ-I-Zusatzstoff

nearly inert addition

3.1.2.3

type II addition

fr: addition de type II

de: Typ II-Zusatzstoff

pozzolanic or latent hydraulic addition

3.1.2.4

admixture

fr: adjuvant

de: Betonzusatzmittel

constituent added during the mixing process in small quantities related to the mass of cement to modify the properties of fresh or hardened concrete

3.1.2.5

aggregate

fr: granulat

de: Gesteinskörnung

natural, artificial, reclaimed or recycled granular mineral constituent suitable for use in concrete

3.1.2.6

all-in aggregate

fr: grave

de: Gesteinskörnungsgemisch

aggregate consisting of a mixture of coarse and fine aggregates with D greater than 4 mm and $d = 0$

3.1.2.7

aggregate size

fr: classe granulaire

de: Korngröße

designation of aggregate in terms of lower (d) and upper (D) sieve sizes expressed as d / D

3.1.2.8

cement

fr: ciment

de: Zement

finely ground inorganic material which, when mixed with water, forms a paste that sets and hardens by means of hydration reactions and processes and which, after hardening, retains its strength and stability even under water

[SOURCE: EN 197-1]

3.1.2.9

finer in concrete

fr: fines du béton

de: Mehlkorn

sum of solid materials in fresh concrete with particle sizes less than or equal to 0,125 mm

3.1.2.10

heavy-weight aggregate

fr: granulat lourd

de: schwere Gesteinskörnung

aggregate in the oven-dry condition having a particle density $\geq 3\,000\text{ kg/m}^3$ when determined according to EN 1097-6

3.1.2.11

lightweight aggregate

fr: granulat léger

de: leichte Gesteinskörnung

aggregate of mineral origin in the oven-dry condition having a particle density $\leq 2\,000\text{ kg/m}^3$ when determined according to EN 1097-6 or a loose oven-dry bulk density $\leq 1\,200\text{ kg/m}^3$ when determined according to EN 1097-3

3.1.2.12

normal-weight aggregate

fr: granulats courants

de: normale Gesteinskörnung

aggregate in the oven-dry condition with a particle density $> 2\,000\text{ kg/m}^3$ and $< 3\,000\text{ kg/m}^3$, when determined according to EN 1097-6

3.1.2.13

polymer fibres

fr: fibres polymères

de: Polymerfasern

straight or deformed pieces of extruded, orientated and cut material, which are suitable to be homogeneously mixed into concrete

[SOURCE: EN 14889-2:2006, 3.2]

3.1.2.14

reclaimed washed aggregate

fr: granulats récupérés par lavage

de: wiedergewonnene gewaschene Gesteinskörnung

aggregates gained by washing fresh concrete

3.1.2.15

reclaimed crushed aggregate

fr: granulats récupérés par concassage

de: wiedergewonnene gebrochene Gesteinskörnung

aggregate gained by crushing hardened concrete that has not been previously used in construction

3.1.2.16

recycled aggregate

fr: gravillon recyclé

de: grobe rezyklierte Gesteinskörnung

aggregate resulting from the processing of inorganic material previously used in construction

3.1.2.17

steel fibres

fr: fibres d'acier

de: Stahlfasern

straight or deformed pieces of cold-drawn steel wire, straight or deformed cut sheet fibres, melt extracted fibres, shaved cold drawn wire fibres or fibres milled from steel blocks, which are suitable to be homogeneously mixed into concrete

[SOURCE: adopted from EN 14889-1:2006, 3.1]

3.1.3 Fresh concrete

3.1.3.1

agitating equipment

fr: cuve agitatrice

de: Rührwerk

equipment generally mounted on a self-propelled chassis and capable of maintaining fresh concrete in a homogeneous state during transport

3.1.3.2

batch

fr: gâchée

de: Charge

quantity of fresh concrete produced in one cycle of operations of a mixer or the quantity discharged during 1 min from a continuous mixer

3.1.3.3

cubic metre of concrete

fr: mètre cube de béton

de: Kubikmeter Beton

quantity of fresh concrete which, when compacted in accordance with the procedure given in EN 12350-6, occupies a volume of 1 m³

3.1.3.4

effective water content

fr: teneur en eau efficace

de: wirksamer Wassergehalt

difference between the total water present in the fresh concrete and the water absorbed by the aggregates

3.1.3.5

entrained air

fr: air entrainé

de: künstliche Luftporen

microscopic air bubbles intentionally incorporated in concrete during mixing, usually by use of a surface active agent; typically between 10 µm and 300 µm in diameter and spherical or nearly so

3.1.3.6

entrapped air

fr: air occlus

de: Lufteinschlüsse

air voids in concrete which are not purposely entrained

3.1.3.7

fresh concrete

fr: béton frais

de: Frischbeton

concrete which is fully mixed and still in a condition that is capable of being compacted by the chosen method

3.1.3.8

load

fr: charge

de: Ladung

quantity of concrete transported in a vehicle comprising one or more batches

3.1.3.9

non-agitating equipment

fr: cuve non agitatrice

de: Ausrüstung ohne Rührwerk

equipment used for transporting concrete without agitation (3.1.3.1)

EXAMPLE dump truck or transport hopper

3.1.3.10

passing ability

fr: aptitude à l'écoulement

de: Blockierneigung

ability of fresh concrete to flow through tight openings such as spaces between steel reinforcing bars without segregation or blocking

3.1.3.11

segregation resistance

fr: résistance à la ségrégation

de: Sedimentationsstabilität

ability of fresh concrete to remain homogeneous in composition while in its fresh state

3.1.3.12

slump-flow

fr: étalement au cône d'Abrams

de: Setzfließmaß

mean diameter of the spread of fresh concrete from a standardized slump cone

3.1.3.13

total water content

fr: teneur en eau totale

de: Gesamtwassergehalt

added water plus water already contained in the aggregates and on the surface of the aggregates plus water in the admixtures and in additions used in the form of a slurry and water resulting from any added ice or steam heating

3.1.3.14

truck mixer

fr: camion malaxeur

de: Fahrnischer

concrete mixer mounted on a self-propelled chassis capable of mixing and delivering a homogeneous concrete

3.1.3.15

viscosity of concrete

fr: viscosité apparente

de: Viskosität

resistance to flow of fresh concrete once flow has started

3.1.3.16

water/cement ratio

fr: rapport eau/ciment

de: Wasserzementwert

ratio of the effective water content to cement content by mass in the fresh concrete

Note 1 to entry: Where additions are used, the water/cement ratio is replaced according to 5.4.2 (3).

3.1.4 Hardened concrete

3.1.4.1

lightweight concrete

fr: béton léger

de: Leichtbeton

concrete in the oven-dry condition having a density of not less than 800 kg/m³ and not more than 2 000 kg/m³

3.1.4.2

hardened concrete

fr: béton durci

de: Festbeton

concrete that is in a solid state and which has developed a certain strength

3.1.4.3

heavy-weight concrete

fr: béton lourd

de: Schwerbeton

concrete in the oven-dry condition having density greater than 2 600 kg/m³

3.1.4.4

normal-weight concrete

fr: béton de masse volumique normale

de: Normalbeton

concrete in the oven-dry condition having a density greater than 2 000 kg/m³ but not exceeding 2 600 kg/m³

3.1.5 Conformity and production control

3.1.5.1

average outgoing quality

AOQ

fr: qualité moyenne après contrôle

AOQ

de: Durchschlupf

AOQ

percentage of the unknown distribution below the required characteristic value multiplied by the corresponding acceptance probability of that distribution when using the applied conformity assessment

Note 1 to entry: In the case of strength, the word 'required' refers to the characteristic strength for the specified compressive strength class or the characteristic strength of the reference concrete of the family.

3.1.5.2

average outgoing quality limit

AOQL

fr: limite de la qualité moyenne après contrôle

AOQL

de: maximaler Durchschlupf

AOQL

maximum average fraction below the required characteristic value in the accepted (or outgoing) concrete production

3.1.5.3

acceptable quality level

AQL

fr: niveau de qualité acceptable

NQA

de: annehmbare Qualitätsgrenze

AQL

percentage of the unknown distribution worse than the specified characteristic of the property under consideration that is considered satisfactory for the production of concrete

3.1.5.4

characteristic strength

fr: résistance caractéristique

de: charakteristische Festigkeit

value of strength below which 5 % of the population of all possible strength determinations of the volume of concrete under consideration, are expected to fall

3.1.5.5

compressive strength class

fr: classe de résistance à la compression

de: Druckfestigkeitsklasse

classification comprising the type of concrete (normal-weight and heavy-weight or lightweight), the minimum characteristic cylinder strength (150 mm diameter by 300 mm length) and the minimum characteristic cube strength (150 mm edge length)

3.1.5.6

conformity test

fr: essai de conformité

de: Konformitätsprüfung

test performed by the producer to assess conformity of the concrete

3.1.5.7

evaluation of conformity

fr: évaluation de conformité

de: Beurteilung der Konformität

systematic examination of the extent to which a product fulfils specified requirements

3.1.5.8

identity test

fr: essai d'identification

de: Identitätsprüfung

test to determine whether selected batches or loads come from a conforming population

3.1.5.9

initial test

fr: essai initial

de: Erstprüfung

test or tests to check before the production starts how a new concrete or concrete family shall be composed in order to meet all the specified requirements in the fresh and hardened states

3.1.5.10

verification

fr: vérification

de: Nachweise

confirmation by examination of objective evidence that specified requirements have been fulfilled.

3.2 Symbols and abbreviations

| | |
|------------|---|
| X0 | Exposure class for no risk of corrosion or attack |
| XC1 to XC4 | Exposure classes for risk of corrosion induced by carbonation |
| XD1 to XD3 | Exposure classes for risk of corrosion induced by chlorides other than from sea water |
| XS1 to XS3 | Exposure classes for risk of corrosion induced by chlorides from sea water |
| XF1 to XF4 | Exposure classes for risk of freeze/thaw attack |
| XA1 to XA3 | Exposure classes for risk of chemical attack |
| S1 to S5 | Consistence classes expressed by slump |
| C0 to C4 | Consistence classes expressed by degree of compactability |
| F1 to F6 | Consistence classes expressed by flow diameter |
| SF1 to SF3 | Consistence classes expressed by slump-flow |
| VS1, VS2 | Viscosity classes for the t_{500} time |
| VF1, VF2 | Viscosity classes for the V-funnel flow time, t_v |
| t_{500} | Time in seconds to flow to a diameter of 500 mm in a slump-flow test |
| t_v | Time in seconds of the flow in a V-funnel test |
| PL1, PL2 | Passing ability classes for the L-box-test |
| PJ1, PJ2 | Passing ability classes for the J-ring-test |

| | |
|---------------|---|
| SR1, SR2 | Segregation resistance classes |
| C.../... | Compressive strength classes in case of normal-weight and heavy-weight concrete |
| LC.../... | Compressive strength classes in case of lightweight concrete |
| SCC | Self-compacting concrete |
| ECPC | Equivalent concrete performance concept |
| EPCC | Equivalent performance of combinations concept |
| f_{ck} | Characteristic compressive strength of concrete NOTE Where used in this standard this applies to both $f_{ck,cyl}$ and $f_{ck,cube}$. |
| $f_{ck,cyl}$ | Characteristic compressive strength of concrete determined by testing cylinders |
| $f_{c,cyl}$ | Compressive strength of concrete determined by testing cylinders |
| $f_{ck,cube}$ | Characteristic compressive strength of concrete determined by testing cubes |
| $f_{c,cube}$ | Compressive strength of concrete determined by testing cubes |
| f_{cm} | Mean compressive strength of concrete NOTE Where used in this standard this applies to both $f_{cm,cyl}$ and $f_{cm,cube}$. |
| $f_{cm,j}$ | Mean compressive strength of concrete at the age of (j) days |
| f_{ci} | Individual test result for compressive strength of concrete |
| $f_{ctk,sp}$ | Characteristic tensile splitting strength of concrete |
| $f_{ctm,sp}$ | Mean tensile splitting strength of concrete |
| $f_{cti,sp}$ | Individual test result for tensile splitting test of concrete |
| ggbs | Ground granulated blastfurnace slag |
| Cl, ... | Chloride class |
| D1,0 to D2,0 | Density classes of lightweight concrete |
| D | Upper sieve size in an aggregate categorised as d / D NOTE EN 12620 permits a defined percentage by mass of particles to be larger than ' D '. |
| D_{lower} | Smallest value of D for the coarsest fraction of aggregates in the concrete permitted by the specification of concrete |
| D_{upper} | Largest value of D for the coarsest fraction of aggregates in the concrete permitted by the specification of concrete |
| D_{max} | Declared value of D of the coarsest fraction of aggregates actually used in the concrete |
| CEM... | Cement type according to EN 197-1 |
| σ | Estimate for the standard deviation of a population |
| s_n | Standard deviation of n consecutive test results |
| AOQ | Average outgoing quality |
| AOQL | Average outgoing quality limit |
| AQL | Average quality level |
| w/c | Water/cement ratio |
| k | Factor which takes into account the activity of a type II addition |
| n | Number |

4 Classification

4.1 Exposure classes related to environmental actions

(1) The environmental actions are classified by exposure classes; see Table 1. The given examples are informative.

NOTE 1 The exposure classes to be selected depend on the provisions valid in the place of use of the concrete. This exposure classification does not exclude consideration of special conditions existing in the place of use of the concrete or the application of protective measures such as the use of stainless steel or other corrosion resistant metal and the use of protective coatings for the concrete or the reinforcement.

NOTE 2 The concrete may be subject to more than one of the actions described in Table 1 and the environmental conditions to which it is subjected may thus need to be expressed as a combination of exposure classes. For a given structural component, different concrete surfaces may be subject to different environmental actions.

(2) In the case of chemical attack, a special study may be needed to establish the relevant exposure condition where there is:

- limits outside of Table 2;
- other aggressive chemicals;
- chemically polluted ground or water;
- high water velocity in combination with the chemicals in Table 2.

NOTE 3 Provisions valid in the place of use may cover some of these situations.

Table 1 — Exposure classes (1 of 2)

| Class designation | Description of the environment | Informative examples where exposure classes may occur |
|--|--|--|
| 1 No risk of corrosion or attack | | |
| X0 | For concrete without reinforcement or embedded metal: All exposures except where there is freeze/thaw, abrasion or chemical attack. For concrete with reinforcement or embedded metal: Very dry | Concrete inside buildings with very low air humidity |
| 2 Corrosion induced by carbonation | | |
| Where concrete containing reinforcement or other embedded metal is exposed to air and moisture, the exposure shall be classified as follows: | | |
| XC1 | Dry or permanently wet | Concrete inside buildings with low air humidity; Concrete permanently submerged in water |
| XC2 | Wet, rarely dry | Concrete surfaces subject to long-term water contact; Many foundations |
| XC3 | Moderate humidity | Concrete inside buildings with moderate or high air humidity; External concrete sheltered from rain |
| XC4 | Cyclic wet and dry | Concrete surfaces subject to water contact, not within exposure class XC2 |

Table 1 (2 of 2)

| Class designation | Description of the environment | Informative examples where exposure classes may occur |
|---|---|---|
| 3 Corrosion induced by chlorides other than from sea water | | |
| Where concrete containing reinforcement or other embedded metal is subject to contact with water containing chlorides, including de-icing salts, from sources other than from sea water, the exposure shall be classified as follows: | | |
| XD1 | Moderate humidity | Concrete surfaces exposed to airborne chlorides |
| XD2 | Wet, rarely dry | Swimming pools; Concrete exposed to industrial waters containing chlorides |
| XD3 | Cyclic wet and dry | Parts of bridges exposed to spray containing chlorides. Pavements, Car park slabs |
| 4 Corrosion induced by chlorides from sea water | | |
| Where concrete containing reinforcement or other embedded metal is subject to contact with chlorides from sea water or air carrying salt originating from sea water, the exposure shall be classified as follows: | | |
| XS1 | Exposed to airborne salt but not in direct contact with sea water | Structures near to or on the coast |
| XS2 | Permanently submerged | Parts of marine structures |
| XS3 | Tidal, splash and spray zones | Parts of marine structures |
| 5 Freeze/thaw attack with or without de-icing agents | | |
| Where concrete is exposed to significant attack by freeze/thaw cycles whilst wet, the exposure shall be classified as follows: | | |
| XF1 | Moderate water saturation, without de-icing agent | Vertical concrete surfaces exposed to rain and freezing |
| XF2 | Moderate water saturation, with de-icing agent | Vertical concrete surfaces of road structures exposed to freezing and airborne de-icing agents |
| XF3 | High water saturation, without de-icing agent | Horizontal concrete surfaces exposed to rain and freezing |
| XF4 | High water saturation, with de-icing agent or sea water | Road and bridge decks exposed to de-icing agents; Concrete surfaces exposed to direct spray containing de-icing agents and freezing Splash zones of marine structures exposed to freezing |
| 6 Chemical attack | | |
| Where concrete is exposed to chemical attack from natural soils and ground water, the exposure shall be classified as follows: | | |
| XA1 | Slightly aggressive chemical environment | Concrete exposed to natural soil and ground water according to Table 2 |
| XA2 | Moderately aggressive chemical environment | Concrete exposed to natural soil and ground water according to Table 2 |
| XA3 | Highly aggressive chemical environment | Concrete exposed to natural soil and ground water according to Table 2 |

(3) The aggressive chemical environments classified in Table 2 are based on natural soil and ground water at water/soil temperatures between 5 °C and 25 °C and a water velocity sufficiently slow to approximate to static conditions. The most onerous value for any single chemical characteristic determines the class. Where two or more aggressive characteristics lead to the same class, the environment shall be classified into the next higher class, unless a special study for this specific case proves that it is not necessary.

Table 2 — Limiting values for exposure classes for chemical attack from natural soil and ground water

| Chemical characteristic | Reference test method | XA1 | XA2 | XA3 |
|--|-----------------------|----------------------------------|-----------------------------------|--------------------------|
| Ground water | | | | |
| SO ₄ ²⁻ mg/l | EN 196-2 | ≥ 200 and ≤ 600 | > 600 and ≤ 3 000 | > 3 000 and ≤ 6 000 |
| pH | ISO 4316 | ≤ 6,5 and ≥ 5,5 | < 5,5 and ≥ 4,5 | < 4,5 and ≥ 4,0 |
| CO ₂ mg/l aggressive | EN 13577 | ≥ 15 and ≤ 40 | > 40 and ≤ 100 | > 100 up to saturation |
| NH ₄ ⁺ mg/l | ISO 7150-1 | ≥ 15 and ≤ 30 | > 30 and ≤ 60 | > 60 and ≤ 100 |
| Mg ²⁺ mg/l | EN ISO 7980 | ≥ 300 and ≤ 1 000 | > 1 000 and ≤ 3 000 | > 3 000 up to saturation |
| Soil | | | | |
| SO ₄ ²⁻ mg/kg ^a total | EN 196-2 ^b | ≥ 2 000 and ≤ 3 000 ^c | > 3 000 ^c and ≤ 12 000 | > 12 000 and ≤ 24 000 |
| Acidity according to Baumann Gully ml/kg | prEN 16502 | > 200 | Not encountered in practice | |
| ^a Clay soils with a permeability below 10 ⁻⁵ m/s may be moved into a lower class. | | | | |
| ^b The test method prescribes the extraction of SO ₄ ²⁻ by hydrochloric acid; alternatively, water extraction may be used, if experience is available in the place of use of the concrete. | | | | |
| ^c The 3 000 mg/kg limit shall be reduced to 2 000 mg/kg, where there is a risk of accumulation of sulfate ions in the concrete due to drying and wetting cycles or capillary suction. | | | | |

4.2 Classes for properties of fresh concrete

4.2.1 Consistence classes

(1) Where concrete is classified with respect to consistence, Tables 3, 4, 5 and 6 apply. In the case of SCC, only the classes in Table 6 apply.

(2) Consistence may also be specified by a target value with tolerances as given in Table 23.

NOTE 1 The classes of consistence in Tables 3 to 6 are not directly related. For earth moist concrete, i.e. concrete with low water content designed to be compacted in special processes, the consistence is not classified.

NOTE 2 For further information see Annex L, line 1.

Table 3 — Slump classes

| Class | Slump tested in accordance with EN 12350-2 mm |
|-----------------------------------|---|
| S1 | 10 to 40 |
| S2 | 50 to 90 |
| S3 | 100 to 150 |
| S4 | 160 to 210 |
| S5 ^a | ≥ 220 |
| ^a See Note 1 to 5.4.1. | |

Table 4 — Compaction classes

| Class | Degree of compactability tested in accordance with EN 12350-4 |
|---|---|
| C0 ^a | ≥ 1,46 |
| C1 | 1,45 to 1,26 |
| C2 | 1,25 to 1,11 |
| C3 | 1,10 to 1,04 |
| C4 ^b | < 1,04 |
| ^a See Note 1 to 5.4.1. | |
| ^b C4 applies only to lightweight concrete. | |

Table 5 — Flow classes

| Class | Flow diameter tested in accordance with EN 12350-5 mm |
|-----------------------------------|--|
| F1 ^a | ≤ 340 |
| F2 | 350 to 410 |
| F3 | 420 to 480 |
| F4 | 490 to 550 |
| F5 | 560 to 620 |
| F6 ^a | ≥ 630 |
| ^a See Note 1 to 5.4.1. | |

Table 6 — Slump-flow classes

| Class | Slump-flow ^a tested in accordance with EN 12350-8 mm |
|--|--|
| SF1 | 550 to 650 |
| SF2 | 660 to 750 |
| SF3 | 760 to 850 |
| ^a The classification is not applicable to concrete with D_{\max} exceeding 40 mm. | |

4.2.2 Classes for additional properties of SCC

(1) Where self-compacting concrete is classified with respect to viscosity, passing ability or sieve segregation resistance, Tables 7 to 11 apply.

(2) Viscosity may also be specified by a target value with tolerances as given in Table 23.

(3) Passing ability may also be specified by a minimum value when determined by the L-box-Test or by a maximum value when determined by the J-Ring-Test.

(4) Sieve segregation may also be specified by a maximum value.

Table 7 — Viscosity classes – t_{500}

| Class | t_{500} ^a tested in accordance with EN 12350-8 |
|--|---|
| | s |
| VS1 | < 2,0 |
| VS2 | ≥ 2,0 |
| ^a The classification is not applicable to concrete with D_{\max} exceeding 40 mm. | |

Table 8 — Viscosity classes – t_v

| Class | t_v ^a tested in accordance with EN 12350-9 |
|--|---|
| | s |
| VF1 | < 9,0 |
| VF2 | 9,0 to 25,0 |
| ^a The classification is not applicable to concrete with D_{\max} exceeding 22,4 mm. | |

NOTE 1 The classes in Tables 7 and 8 are similar but not exactly correlated.

Table 9 — Passing ability classes - L-box

| Class | L-box ratio tested in accordance with EN 12350-10 |
|--------------|--|
| PL1 | ≥ 0,80 with 2 rebars |
| PL2 | ≥ 0,80 with 3 rebars |

Table 10 — Passing ability classes – J-ring

| Class | J-ring step ^a tested in accordance with EN 12350-12 |
|--|---|
| | mm |
| PJ1 | ≤ 10 with 12 rebars |
| PJ2 | ≤ 10 with 16 rebars |
| ^a The classification is not applicable to concrete with a maximum aggregate size exceeding 40 mm. | |

NOTE 2 The classes in Tables 9 and 10 are similar but not exactly correlated.

Table 11 — Sieve segregation resistance classes

| Class | Segregated portion ^a tested in accordance with EN 12350-11 % |
|--|--|
| SR1 | ≤ 20 |
| SR2 | ≤ 15 |
| ^a The classification is not applicable to concrete with D_{\max} exceeding 40 mm. | |

4.3 Classes for properties of hardened concrete

4.3.1 Compressive strength classes

(1) Where concrete is classified with respect to its compressive strength, Table 12 applies for normal-weight and heavy-weight concrete and Table 13 applies for lightweight concrete. The characteristic compressive strength at 28 days of 150 mm diameter by 300 mm cylinders ($f_{ck,cyl}$) or the characteristic compressive strength at 28 days of 150 mm cubes ($f_{ck,cube}$), tested in accordance with EN 12390-3 may be used for classification.

NOTE For further information see Annex L, line 2.

Table 12 — Compressive strength classes for normal-weight and heavy-weight concrete

| Compressive strength class | Minimum characteristic cylinder strength $f_{ck,cyl}$ N/mm² | Minimum characteristic cube strength $f_{ck,cube}$ N/mm² |
|-----------------------------------|--|---|
| C8/10 | 8 | 10 |
| C12/15 | 12 | 15 |
| C16/20 | 16 | 20 |
| C20/25 | 20 | 25 |
| C25/30 | 25 | 30 |
| C30/37 | 30 | 37 |
| C35/45 | 35 | 45 |
| C40/50 | 40 | 50 |
| C45/55 | 45 | 55 |
| C50/60 | 50 | 60 |
| C55/67 | 55 | 67 |
| C60/75 | 60 | 75 |
| C70/85 | 70 | 85 |
| C80/95 | 80 | 95 |
| C90/105 | 90 | 105 |
| C100/115 | 100 | 115 |

Table 13 — Compressive strength classes for lightweight concrete

| Compressive strength class | Minimum characteristic cylinder strength $f_{ck,cyl}$ N/mm ² | Minimum characteristic cube strength ^a $f_{ck,cube}$ N/mm ² |
|----------------------------|---|---|
| LC8/9 | 8 | 9 |
| LC12/13 | 12 | 13 |
| LC16/18 | 16 | 18 |
| LC20/22 | 20 | 22 |
| LC25/28 | 25 | 28 |
| LC30/33 | 30 | 33 |
| LC35/38 | 35 | 38 |
| LC40/44 | 40 | 44 |
| LC45/50 | 45 | 50 |
| LC50/55 | 50 | 55 |
| LC55/60 | 55 | 60 |
| LC60/66 | 60 | 66 |
| LC70/77 | 70 | 77 |
| LC80/88 | 80 | 88 |

^a Other values may be used if the relationship between these and the reference cylinder strength is established and documented.

4.3.2 Density classes for lightweight concrete

- (1) Table 14 applies where lightweight concretes are classified by density classes.
- (2) The density of lightweight concrete may also be specified by a target value.

Table 14 — Density classes for lightweight concrete

| Density class | D1,0 | D1,2 | D1,4 | D1,6 | D1,8 | D2,0 |
|---|-------------------|---------------------|---------------------|---------------------|---------------------|---------------------|
| Range of density tested in accordance with EN 12390-7 kg/m ³ | ≥ 800 and ≤ 1 000 | > 1 000 and ≤ 1 200 | > 1 200 and ≤ 1 400 | > 1 400 and ≤ 1 600 | > 1 600 and ≤ 1 800 | > 1 800 and ≤ 2 000 |

5 Requirements for concrete and methods of verification

5.1 Basic requirements for constituents

5.1.1 General

(1) Only constituents with established suitability for the particular intended use of the concrete conforming to this European Standard shall be used.

(2) Where there is no European Standard for a particular constituent which refers specifically to the use of this constituent in concrete conforming to this standard, or where there is an existing European Standard which does not cover the particular product or where the constituent deviates significantly from the European Standard, the establishment of suitability may result from:

- a European Technical Assessment which refers specifically to the use of the constituent in concrete conforming to this standard;
- provisions valid in the place of use of the concrete which refers specifically to the use of the constituent in concrete conforming to this standard.

NOTE 1 Where general suitability is established for a constituent, this does not indicate suitability in every intended use of the concrete and for every concrete composition.

NOTE 2 European Technical Assessments for constituents establish their general suitability for the use in concrete conforming to this standard. EN 206 is not a harmonised European Standard and the durability provisions for concrete are given in provisions valid in the place of use. Therefore to establish specific suitability, it is necessary to assess the "Product" against the durability provisions valid in the place of use.

(3) Constituents shall not contain harmful ingredients in such quantities as may be detrimental to the durability of the concrete or cause corrosion of the reinforcement and shall be suitable for the intended use in concrete.

5.1.2 Cement

(1) General suitability is established for cement conforming to EN 197-1. Suitability for concrete for massive structures (e.g. dams, see Clause 1 (6), first bullet point) is established for very low heat special cement conforming to EN 14216.

(2) Suitability of calcium aluminates cement (conforming to EN 14647) and supersulfated cement (conforming to EN 15743) may be established by provisions valid in the place of use.

NOTE For further information see Annex L, line 3.

5.1.3 Aggregates

(1) General suitability is established for:

- natural normal-weight aggregates, heavy-weight aggregates and air-cooled blast furnace slag conforming to EN 12620;
- lightweight aggregates conforming to prEN 13055;
- reclaimed aggregates conforming to 5.2.3.3;

and conforming to the categories given in EN 12620 or in prEN 13055 established in the provisions valid in the place of use.

NOTE Recommendations for the use of aggregates (categories) are given in Annex E.

(2) Recycled and manufactured aggregates, other than air-cooled blast furnace slag, may be used as aggregate for concrete if the suitability is established by provisions valid in the place of use.

5.1.4 Mixing water

(1) General suitability is established for mixing water conforming to EN 1008.

5.1.5 Admixtures

(1) General suitability is established for admixtures conforming to EN 934-2.

(2) Admixtures not included in EN 934-2 (e.g. pumping agents) shall conform to the general requirements in EN 934-1 and to the provisions valid in the place of use.

NOTE EN 934-1:2008 gives appropriate general requirements in Table 1, Clause 5 and Clause 6.

5.1.6 Additions (including mineral fillers and pigments)

(1) General suitability as type I addition is established for:

- filler aggregate conforming to EN 12620 or prEN 13055;
- pigments conforming to EN 12878; for reinforced concrete, only category B pigments.

(2) General suitability as type II addition is established for:

- fly ash conforming to EN 450-1;
- silica fume conforming to EN 13263-1;
- ground granulated blastfurnace slag conforming to EN 15167-1.

5.1.7 Fibres

(1) General suitability is established for:

- steel fibres conforming to EN 14889-1;
- polymer fibres conforming to EN 14889-2.

5.2 Basic requirements for composition of concrete

5.2.1 General

(1) The concrete composition and the constituents for designed or prescribed concrete shall be selected (see 6.1) to satisfy the requirements specified for fresh and hardened concrete, including consistence, density, strength and durability, taking into account the production process and the intended method of execution of concrete works.

(2) Where not detailed in the specification of concrete, the producer shall select types and classes of constituents from those with established suitability in provisions valid in the place of use for the specified environmental conditions.

(3) The concrete should be designed so as to minimise segregation and bleeding of the fresh concrete unless specified otherwise.

(4) In the case of designed concrete, the limiting values shall be specified in terms of minimum or maximum values and in the case of prescribed concrete, the composition shall be specified by target values.

(5) For standardized prescribed concretes, the provisions valid in the place of use shall specify the prescription and list the types and categories of constituent materials with established suitability. These prescriptions shall satisfy the criterion for adoption of initial tests given in A.5.

(6) Annex D specifies additional requirements for concrete for special geotechnical works.

5.2.2 Selection of cement

(1) Cement shall be selected from those for which the suitability is established, taking into account the:

- execution of the work;
- intended use of concrete;
- curing conditions (e.g. heat treatment);

- dimensions of the structure (the heat development);
- environmental conditions to which the structure is to be exposed (see 4.1);
- potential reactivity of aggregate to the alkalis from the constituents.

5.2.3 Selection of aggregates

5.2.3.1 General

(1) Aggregate type and categories, e.g. grading, flakiness, freeze/thaw resistance, abrasion resistance, fines, shall be selected taking into account the:

- execution of the work;
- intended use of concrete;
- environmental conditions to which the concrete is to be exposed;
- any requirements for exposed aggregate or aggregate for tooled concrete finishes.

(2) D_{\max} shall be $\geq D_{\text{lower}}$ and $\leq D_{\text{upper}}$.

5.2.3.2 All-in aggregate

(1) All-in aggregate with a size range greater than 0/8 conforming to EN 12620 shall be used only in concrete with compressive strength classes $\leq C12/15$.

5.2.3.3 Reclaimed aggregate

(1) Reclaimed aggregate may be used as aggregate for concrete provided it is only used internally by the producer or a group of producers.

(2) Reclaimed aggregate shall not be added in quantities greater than 5 % by mass of the total aggregate if they are undivided.

(3) Where the quantities of the reclaimed washed aggregates are greater than 5 % by mass of the total aggregate, they shall be divided into separate coarse and fine aggregates and conform to EN 12620.

(4) Where the quantities of the reclaimed crushed aggregates are greater than 5 % by mass of the total aggregate they shall be treated as recycled aggregates.

5.2.3.4 Recycled aggregates

(1) Recommendations for the use of coarse recycled aggregates are given in Annex E.

NOTE No recommendations for the use of fine recycled aggregate are given in this standard.

5.2.3.5 Resistance to alkali-silica reaction

(1) Where aggregates contain varieties of silica susceptible to attack by alkalies (Na_2O and K_2O originating from cement, de-icing chemicals or other sources) and the concrete is exposed to humid conditions, actions shall be taken to prevent deleterious alkali-silica reaction using provisions valid in the place of use.

NOTE For further information see Annex L, line 4.

5.2.4 Use of mixing water

(1) Water recovered from processes in the concrete industry on its own or combined with potable water or ground water conforming to EN 1008 may be used as mixing water for concrete with or without reinforcement or embedded metal and also for prestressed concrete, provided the requirements according to EN 1008 are met.

5.2.5 Use of additions

5.2.5.1 General

(1) The quantities of type I and type II additions to be used in concrete shall be covered by the initial tests (see Annex A).

NOTE For further information see Annex L, line 5.

(2) Type II additions listed in 5.1.6 may be taken into account in the concrete composition with respect to the cement content and the water/cement ratio if the suitability is established by any of the concepts according to (3). Type I additions and type II additions other than those defined in 5.1.6 (2) may be taken into account if the suitability has been established in provisions valid in the place of use.

(3) The suitability of the k -value concept and the principles of the equivalent performance concepts (equivalent concrete performance concept (ECPC), equivalent performance of combinations concept (EPCC)) are established.

(4) Subclause 5.2.5.2 provides k -values for fly ash and silica fume as well as recommendations for ground granulated blastfurnace slag, which are suitable for general use. Modifications to the rules of application for the k -value concept given in 5.2.5.2.2, 5.2.5.2.3 and 5.2.5.2.4 may be applied where their suitability has been established (e.g. higher k -values, increased proportions of additions, combinations of additions and other cements).

(5) The equivalent performance concepts (see 5.2.5.3 and 5.2.5.4) for the use of additions may be applied where suitability has been established.

NOTE For further information see Annex L, line 6.

(6) The general principles and the additional conditions of the k -value concept as well as the general principles of the equivalent concrete performance concept and the equivalent performance of combinations concept for use of additions are given in the following subclauses.

NOTE The CEN/TR 16639 provides more detailed information on these concepts [26].

5.2.5.2 k -value concept for fly ash, silica fume and ground granulated blast furnace slag

5.2.5.2.1 General

(1) The k -value concept is a prescriptive concept. It is based on the comparison of the durability performance (or strength as a proxy-criterion for durability where appropriate) of a reference concrete with cement "A" against a test concrete in which part of cement "A" is replaced by an addition as function of the water/cement ratio and the addition content.

(2) The k -value concept permits type II additions to be taken into account:

- by replacing the term "water/cement ratio" with "water/(cement + $k \times$ addition) ratio"; and
- the amount of (cement + $k \times$ addition) shall not be less than the minimum cement content required for the relevant exposure class (see 5.3.2).

(3) The rules of application of the k -value concept for fly ash conforming to EN 450-1, silica fume conforming to EN 13263-1 and ground granulated blastfurnace slag conforming to EN 15167-1 together with cement of type CEM I and CEM II/A conforming to EN 197-1 are given in the following subclauses.

5.2.5.2.2 k -value for fly ash conforming to EN 450-1

(1) A k -value of 0,4 is permitted for concrete containing cement types CEM I and CEM II/A conforming to EN 197-1.

(2) For use with CEM I cement, the maximum amount of fly ash to be taken into account shall meet the requirement:

$$\text{fly ash/cement} \leq 0,33 \text{ by mass.}$$

(3) For use with CEM II/A cement, the maximum amount of fly ash to be taken into account shall meet the requirement:

$$\text{fly ash/cement} \leq 0,25 \text{ by mass.}$$

(4) If a greater amount of fly ash is used, the excess shall not be taken into account for the calculation of the water/(cement + $k \times$ fly ash) ratio and the minimum cement content.

5.2.5.2.3 k -value for silica fume of class 1 conforming to EN 13263-1

(1) The following k -values are permitted to be applied for concrete containing cement types CEM I and CEM II/A (except cements including silica fume) conforming to EN 197-1:

— for specified water/cement ratio $\leq 0,45$ $k = 2,0$;

— for specified water/cement ratio $> 0,45$ $k = 2,0$ except for exposure classes XC and XF, where $k = 1,0$.

(2) The maximum amount of silica fume of class 1 to be taken into account shall meet the requirement:

$$\text{silica fume/cement} \leq 0,11 \text{ by mass.}$$

(3) If a greater amount of silica fume of class 1 is used, the excess shall not be taken into account for the calculation of the water/(cement + $k \times$ silica fume) ratio and the minimum cement content.

(4) The amount of cement shall not be reduced by more than 30 kg/m^3 below the minimum cement content required for the relevant exposure class.

NOTE Provisions valid in place of use apply for the silica fume of class 2.

5.2.5.2.4 k -value for ground granulated blastfurnace slag conforming to EN 15167-1

(1) The k -value and the maximum amount of ground granulated blastfurnace slag (ggbs) to be taken into account for the k -value concept shall be in accordance with the provisions valid in the place of use.

NOTE For further information see Annex L, line 7.

5.2.5.3 Principles of the Equivalent Concrete Performance Concept

(1) The principles of the “Equivalent Concrete Performance Concept” permit amendments to the requirements for minimum cement content and maximum water/cement ratio when one or more specific additions and one or more specific cements are used, for which the manufacturing source and characteristics of each are clearly defined and documented.

(2) Within the requirements of 5.2.5.1, it shall be proven that the concrete has an equivalent performance especially with respect to its reaction to environmental actions when compared with a reference concrete in conformity with the requirements for the relevant exposure class (see 5.3.2).

(3) The concept shall be used only with cements conforming to EN 197-1 plus one or more additions.

NOTE 1 Provisions valid in the place of use may place restrictions on the cement types and fly ash loss-on-ignition categories to align the composition to currently permitted cements.

NOTE 2 The CEN/TR 16639 provides more detailed information on this concept.

5.2.5.4 Principles of the Equivalent Performance of Combinations Concept

(1) The principles of the "Equivalent Performance of Combinations Concept" permit a defined range of combinations of cement conforming to EN 197-1 and addition (or additions) having established suitability (see 5.1.1) that may count fully towards requirements for maximum water to cement ratio and minimum cement content which are specified for a concrete.

(2) The elements of the methodology are:

- identify a cement type that conforms to a European cement standard and that has the same or similar composition to the intended combination;
- assess whether the concretes produced with the combination have similar strength and durability as concretes made with the identified cement type for the relevant exposure class;
- implement a production control that ensures these requirements for the concretes containing the combination are defined and implemented.

NOTE The CEN/TR 16639 provides information on the application of this concept in three CEN member states.

5.2.6 Use of admixtures

(1) The total amount of admixtures, if any, shall not exceed the maximum dosage recommended by the admixture producer and not exceed 50 g of admixture (as supplied) per kilogram of cement unless the influence of the higher dosage on the performance and the durability of the concrete is established and taken into account.

(2) Admixtures used in quantities less than 2 g/kg of cement shall be dispersed in part of the mixing water except where the admixture cannot be dispersed homogeneously in the mixing water (e.g. because it forms a gel). In this case, other methods of feeding into the concrete may be used.

(3) If the total quantity of liquid admixtures exceeds 3 l/m³ of concrete, its water content shall be taken into account when calculating the water/cement ratio.

(4) Where more than one admixture is used, the compatibility of the admixtures shall be checked in the initial tests.

NOTE For further information see Annex L, line 8.

5.2.7 Use of fibres

(1) Fibres of the type and quantity specified shall be added to the mix in a procedure that ensures that they are dispersed uniformly throughout the batch.

NOTE 1 For further information see Annex L, line 9.

NOTE 2 EN 14889-1 and EN 14889-2 require fibres for structural use to have an attestation of conformity system 1 and accept fibres for other uses having an attestation of conformity system 3.

(2) Steel fibres conforming to EN 14889-1 with zinc coatings shall not be used in concrete unless it is proven that hydrogen formation in the concrete is prevented.

5.2.8 Chloride content

(1) The chloride content of a concrete, expressed as the percentage of chloride ions by mass of cement, shall not exceed the value for the selected class given in Table 15.

Table 15 — Maximum chloride content of concrete

| Concrete use | Chloride content class ^a | Maximum Cl ⁻ content by mass of cement ^b % |
|---|-------------------------------------|---|
| Not containing steel reinforcement or other embedded metal with the exception of corrosion-resisting lifting devices | CI 1,00 | 1,00 |
| Containing steel reinforcement or other embedded metal | CI 0,20 | 0,20 |
| | CI 0,40 ^c | 0,40 |
| Containing prestressing steel reinforcement in direct contact with concrete | CI 0,10 | 0,10 |
| | CI 0,20 | 0,20 |
| <p>^a For a specific concrete use, the class to be applied depends upon the provisions valid in the place of use of the concrete.</p> <p>^b Where additions are used and are taken into account for the cement content, the chloride content is expressed as the percentage chloride ion by mass of cement plus total mass of additions that are taken into account.</p> <p>^c Different chloride content classes may be permitted for concrete containing CEM III-cements according to provisions valid in the place of use.</p> | | |

(2) Calcium chloride and chloride based admixtures shall not be added to concrete containing steel reinforcement, prestressing steel reinforcement or other embedded metal.

(3) The method for determining the chloride content of constituents shall be in accordance with the relevant test method for the constituent.

(4) For the determination of the chloride content of the concrete, the sum of the contributions from the constituents shall be determined using one of, or a combination of, the following methods:

- calculation based on the maximum chloride content of the constituent either permitted in the standard for the constituent or declared by the producer of each constituent;
- calculation based on the chloride content of the constituents calculated at least monthly from the sum of the means of the last 25 determinations of chloride content plus $1,64 \times$ the calculated standard deviation for each constituent material.

NOTE The latter method is particularly applicable to sea-dredged aggregates and for those cases where there is no declared or standard maximum value.

5.2.9 Concrete temperature

(1) The temperature of fresh concrete shall not be less than 5 °C at the time of delivery. Where a requirement for a different minimum temperature or a maximum temperature of fresh concrete is necessary, they shall be specified together with the permitted tolerances. Any requirement for artificial cooling or heating of the concrete prior to delivery has to be agreed between the producer and the user.

5.3 Requirements related to exposure classes

5.3.1 General

(1) Requirements for the concrete to withstand the environmental actions are given either in terms of limiting values for concrete composition and established concrete properties (see 5.3.2), or the requirements may be derived from performance-related methods (see 5.3.3). The requirements shall take into account the design working life of the concrete structure.

5.3.2 Limiting values for concrete composition

(1) Requirements for the method of specification to resist environmental actions are given in this standard in terms of established concrete properties and limiting values of composition.

NOTE 1 Due to the lack of experience on how the classification of the environmental actions on concrete reflect local differences in the same nominal exposure class, the specific values of these requirements for the applicable exposure classes are given in the provisions valid in the place of use.

(2) The requirements for each exposure class shall be specified in terms of:

- permitted types and classes of constituents;
- maximum water/cement ratio;
- minimum cement content;
- minimum concrete compressive strength class (optional);

and, where relevant,

- minimum air-content of the concrete.

NOTE 2 A recommendation for the choice of limiting values for concrete composition and properties is given in Annex F when using common cements conforming to EN 197-1, for which suitability for use in a considered exposure class has been established.

(3) The provisions valid in the place of use of the concrete shall include requirements under the assumption of an intended design working life of at least 50 years under the anticipated maintenance conditions.

NOTE 3 For shorter or longer design working life, less onerous or more severe requirements may be necessary. Guidance for the interpretation of "end of design working life", and how to calibrate/validate the limiting values for concrete composition to be given in the provisions valid in the place of use, can be found in ISO 16204.

(4) For combined exposure classes, the most onerous of each of the requirements apply.

5.3.3 Performance-related methods

(1) The requirements related to exposure classes may be established by using performance-related methods for durability and may be specified in terms of performance-related parameters, e.g. scaling of concrete in a freeze/thaw test. The application of a performance based method depends on the provisions valid in the place of use of the concrete.

NOTE A suite of European performance-related test methods is being developed, e.g. CEN/TS 12390-9, CEN/TS 12390-10, CEN/TS 12390-11 and CEN/TR 15177 and the framework for the equivalent durability procedure has been published as CEN/TR 16563.

5.4 Requirements for fresh concrete

5.4.1 Consistence, viscosity, passing ability and resistance to segregation

(1) Where the consistence of concrete is to be determined, it shall be measured either by means of:

- slump test according to EN 12350-2;
- degree of compactability according to EN 12350-4;
- flow table test according to EN 12350-5;
- slump flow test according to EN 12350-8;
- specific methods to be agreed upon between the specifier and the producer for concrete for special applications (e.g. earth moist concrete).

NOTE For further information see Annex L, line 10.

(2) Where the viscosity of self-compacting concrete is to be determined, it shall be measured either by means of:

- time t_{500} according to EN 12350-8;
- time t_v according to EN 12350-9.

(3) Where the passing ability of self-compacting concrete is to be determined, it shall be measured either by means of:

- L-box test according to EN 12350-10;
- J-ring test according to EN 12350-12.

(4) Where the resistance to segregation of self-compacting concrete is to be determined, it shall be measured by means of sieve segregation resistance test according to EN 12350-11.

NOTE The consistence, viscosity, passing ability and resistance to segregation can also be determined by alternative test methods valid in the place of use if there is an established relationship (see 9.4).

(5) The point of conformity to the designated properties shall be at the time of use of the concrete or in the case of ready-mixed concrete, at the time of delivery.

(6) If concrete is delivered in a truck mixer or agitating equipment, the properties shall be measured using either a composite sample or a spot sample in accordance with EN 12350-1.

(7) The properties may be specified either by reference to a class according to 4.2.1 or 4.2.2 or by a target value. The related tolerances for target values are given in Table 23.

5.4.2 Cement content and water/cement ratio

(1) Where the cement, water, or addition content is to be determined, the cement content, addition content or added water shall be taken either as recorded on the print-out of the batch recorder or where recording equipment is not used, from the production record in connection with the batching instruction.

(2) Where the water/cement ratio of concrete is to be determined, it shall be calculated on the basis of the determined cement content and the effective water content (for liquid admixtures see 5.2.6(3)). The water absorption of normal-weight and heavy-weight aggregates shall be determined in accordance with EN 1097-6. The water absorption of coarse lightweight aggregate in the fresh concrete shall be taken as the value

obtained at 1 h based on the method given in EN 1097-6:2013, Annex C, using the as-used moisture state instead of the oven-dry state.

NOTE 1 For further information see Annex L, line 11.

NOTE 2 The test according to EN 1097-6 can be modified to take into account all the fines, where permitted in provisions valid in the place of use.

(3) Where additions are taken into account in the concrete composition with respect to the minimum cement content and the maximum water/cement ratio, the cement content is replaced by:

- (cement + $k \times$ addition) content; or,
- (cement + addition) content;

depending on the concept in use (see 5.2.5).

(4) Where the determination of the cement content, the addition content or water/cement ratio of fresh concrete by analysis is required, the test method and tolerances shall be agreed between the specifier and producer.

NOTE 3 See CR 13902 [28]

5.4.3 Air content

(1) Where the air content of the concrete is to be determined, it shall be measured in accordance with EN 12350-7 for normal-weight and heavy-weight concrete and in accordance with ASTM C 173 for light-weight concrete.

5.4.4 Fibre content

(1) Where the fibre content of fresh concrete is to be determined, it shall be taken either as recorded on the print-out of the batch recorder or where recording equipment is not used, from the production record in connection with the batching instruction.

5.5 Requirements for hardened concrete

5.5.1 Strength

5.5.1.1 General

(1) Where the strength is to be determined, it shall be based on tests carried out on either 150/300 mm cylinders or 150 mm cubes conforming to EN 12390-1 and made and cured in accordance with EN 12390-2 from samples taken in accordance with EN 12350-1.

(2) In assessing the strength, other sizes of moulded specimens and other curing regimes may be used provided the relationship to those standardized has been established and documented.

5.5.1.2 Compressive strength

(1) Where the compressive strength is to be determined, it shall be expressed as $f_{c,cyl}$ where determined using cylindrical specimens and $f_{c,cube}$ where determined using cubical specimens, in accordance with EN 12390-3.

(2) Whether the compressive strength is to be assessed on the basis of cylinder or cube tests shall be declared by the producer in due time before delivery. If a different method is to be used, this has to be agreed between the specifier and the producer.

(3) Unless specified otherwise, the compressive strength is determined on specimens tested at 28 days. For particular uses, it may be necessary to specify the compressive strength at ages earlier or later than 28 days (e.g. for massive structural elements) or after storage under special conditions (e.g. heat treatment).

(4) The characteristic strength of the concrete shall be equal to or greater than the minimum characteristic compressive strength for the specified compressive strength class, see Tables 12 and 13.

(5) If the testing for compressive strength is expected to give non-representative values, e.g. when concrete of consistence class C0 or stiffer than S1 is tested, either the test method shall be modified or the compressive strength may be assessed in the existing structure or structural component.

NOTE For further information see Annex L, line 12.

5.5.1.3 Tensile splitting strength

(1) Where the tensile splitting strength of concrete is to be determined, it shall be measured in accordance with EN 12390-6. Unless specified otherwise, the tensile splitting strength is determined on specimens tested at 28 days.

(2) The characteristic tensile splitting strength of the concrete shall be equal to or greater than the specified characteristic tensile splitting strength.

NOTE Where flexural strength is to be determined, the same approach can be used. In this case the appropriate test standard is EN 12390-5.

5.5.2 Density

(1) According to its density, concrete in the oven-dry condition is defined as normal-weight concrete, lightweight concrete or heavyweight concrete (see definitions).

(2) Where the density of concrete in the oven-dry condition is to be determined, it shall be measured in accordance with EN 12390-7.

(3) For normal-weight concrete, the density in the oven-dry condition shall be greater than 2 000 kg/m³ and not exceed 2 600 kg/m³. For lightweight concrete, the density in the oven-dry condition shall be within the limiting values for the specified density class, see Table 14. For heavy-weight concrete, the density in the oven-dry condition shall be greater than 2 600 kg/m³. Where the density is specified as a target value, a tolerance of ± 100 kg/m³ applies unless specified otherwise.

(4) Where determining the conformity of lightweight concrete to the specified density class, the density determination of hardened lightweight concrete shall be in accordance with EN 12390-7 and for the oven-dry condition. When determining the conformity of lightweight concrete to the target density in accordance with 8.2.3.3, the density determination of hardened lightweight concrete shall be in accordance with EN 12390-7 and for either the oven-dry condition or the condition specified.

5.5.3 Resistance to water penetration

(1) Where resistance to water penetration on test specimens is to be determined, the method (e.g. EN 12390-8) and conformity criteria shall be agreed between the specifier and producer.

(2) In the absence of an agreed test method, resistance to water penetration may be specified indirectly by limiting values for concrete composition.

5.5.4 Reaction to fire

(1) Concrete which is composed of mineral aggregates conforming to 5.1.3, cement conforming to 5.1.2, admixtures conforming to 5.1.5, additions conforming to 5.1.6, fibres conforming to 5.1.7 or other inorganic constituent materials conforming to 5.1.1, is classified as Euro class A1 and does not require testing.¹⁾

6 Specification of concrete

6.1 General

(1) The specifier of the concrete shall ensure that all the relevant requirements for concrete properties are included in the specification of concrete given to the producer. The specifier shall also specify any requirements for concrete properties that are needed for transportation after delivery, placing, compaction, curing or further treatment. The specification shall, if necessary, include any special requirements (e.g. for obtaining an architectural finish).

(2) The specifier shall take account of:

- the application of the fresh and hardened concrete;
- the curing conditions;
- the dimensions of the structure (the heat development);
- the environmental actions to which the structure is to be exposed;
- design working life;
- any requirements for exposed aggregate or tooled concrete finishes;
- all requirements that have an impact on the specified D_{upper} and D_{lower} ;

NOTE 1 Such requirements are given in, for example, EN 1992-1-1 and EN 13670.

- any restrictions on the use of constituents with established suitability, e.g. resulting from exposure classes.

NOTE 2 The provisions valid in the place of use of the concrete may contain requirements for some of these considerations.

(3) Concrete shall be specified either as designed concrete referring in general to classification or target values given in Clause 4 and requirements given in 5.3 to 5.5 (see 6.2) or as prescribed concrete by prescribing the composition (see 6.3). The basis for designing or prescribing a concrete composition shall be results from initial tests (see Annex A) or information obtained from long-term experience with comparable concrete, taking into account the basic requirements for constituents (see 5.1) and concrete composition (see 5.2 and 5.3.2).

(4) For prescribed concrete, the specifier is responsible for ensuring that the specification of concrete conforms to the general requirements in this European Standard and the specified composition is capable of achieving the intended performance of the concrete in both the fresh and hardened states. The specifier shall maintain and update supporting documentation relating the prescription to the intended performance, see 9.5. In the case of standardized prescribed concrete, this is the responsibility of the national standards bodies.

NOTE 3 For prescribed concrete, the assessment of conformity is based solely on the achievement of the specified composition and not on any performance intended by the specifier.

1) See Commission Decision (94/611/EC) [3].

6.2 Specification for designed concrete

6.2.1 General

(1) Designed concrete shall be specified by means of basic requirements from 6.2.2, to be given in all cases, and additional requirements from 6.2.3, to be specified where required.

(2) Abbreviations to be used in specifications are given in Clause 11.

6.2.2 Basic requirements

(1) The specification of concrete shall contain:

- a) a requirement to conform to this standard;
- b) compressive strength class;
- c) exposure classes (see Clause 11 for the abbreviated format);
- d) D_{upper} and D_{lower} ;

NOTE 1 D_{upper} should not be greater than d_g according to EN 1992-1-1.

- e) chloride content class in accordance with Table 15.

(2) In addition, for lightweight concrete:

- f) density class or target density.

(3) In addition, for heavy-weight concrete:

- g) target density.

(4) In addition, for ready-mixed concrete and site-mixed concrete:

- h) consistence class or a target value for consistence.

NOTE 2 See Annex G for guidance on specifying the consistence of self-compacting concrete.

6.2.3 Additional requirements

(1) The following items may be specified using performance requirements and test methods where they are appropriate:

- specific types or classes of cement;
- specific types or categories of aggregate;

NOTE In these cases, concrete composition to minimise deleterious alkali-silica reaction is the responsibility of the specifier (see 5.2.3.5).

- type, function (i.e. structural or non-structural) and minimum content of fibres or performance classes of fibre reinforced concrete. In the case of performance classes, the classes, the test methods and the conformity criteria shall be specified;
- characteristics required to resist freeze/thaw attack (e.g. minimum air content, see 5.4.3).

NOTE 2 For further information see Annex L, line 13.

- requirements for the temperature of the fresh concrete where different from that in 5.2.9;
- strength development (see Table 16);
- heat development during hydration;
- retarded stiffening;
- resistance to water penetration;
- resistance to abrasion;
- tensile splitting strength (see 5.5.1.3);
- drying shrinkage, creep, modulus of elasticity (e.g. as indicated in A.4 (9));
- additional specifications for concrete for special geotechnical works (see Annex D);
- additional properties for self-compacting concrete (see Annex G);
- other technical requirements (e.g. requirements related to the achievement of a particular finish or special method of placing, consistence retention time).

6.3 Specification for prescribed concrete

6.3.1 General

(1) Prescribed concrete shall be specified by basic requirements from 6.3.2, to be given in all cases, and additional requirements from 6.3.3 to be specified where required.

6.3.2 Basic requirements

(1) The specification of concrete shall contain:

- a) a requirement to conform to this standard;
- b) cement type and strength class;
- c) target cement content;
- d) either target w/c ratio or consistence in terms of class or target value;

NOTE 1 For further information see Annex L, line 14.

- e) types, categories of aggregates and maximum chloride content of aggregates;
- f) in the case of lightweight or heavy-weight concrete the maximum or minimum density of aggregate as appropriate;
- g) maximum aggregate size D_{upper} , D_{lower} and any limitations for the grading category;

NOTE 2 D_{upper} should not be greater than d_g according to EN 1992-1-1.

- h) type and quantity of admixtures, additions or fibres, if any;
- i) if admixtures, additions or fibres are used, sources of these constituents and of the cement as a substitute for characteristics that are not definable by other means.

6.3.3 Additional requirements

(1) The specification of concrete may contain:

- sources of some, or all, concrete constituents as a substitute for characteristics that are not definable by other means;
- additional requirements for aggregates;
- requirements for the temperature of the fresh concrete where different from that in 5.2.9;
- other technical requirements.

6.4 Specification of standardized prescribed concrete

(1) Standardized prescribed concrete shall be specified by citing:

- the standard valid in the place of use of the concrete giving the relevant requirements;
- the notation of the concrete in that standard.

(2) Standardized prescribed concrete shall be used only for:

- normal-weight concrete for plain and reinforced concrete structures;
- compressive strength classes for design \leq C16/20 unless strength class C20/25 is permitted in provisions valid in the place of use of the concrete;
- exposure classes X0 and XC1 unless provisions valid in the place of use of the concrete permit other exposure classes.

7 Delivery of fresh concrete

7.1 Information from the user of the concrete to the producer

(1) The user shall agree with the producer the

- delivery date, time and rate;

and where appropriate inform the producer of:

- special transport on site;
- special methods of placing;
- limitation of delivery vehicle, e.g. type (agitating/non-agitating equipment), size, height or gross weight.

7.2 Information from the producer of the concrete to the user

(1) The following information shall be provided for designed concrete by the producer on request from the user:

- a) type and strength class of cement and type of aggregates;
- b) type of admixtures, type of additions, if any;
- c) description of the fibres according to EN 14889-1 or EN 14889-2 and content, if specified;

- d) description of the fibres according to EN 14889-1 or EN 14889-2, if specified by performance class of fibre reinforced concrete;
- e) target water/cement ratio;
- f) results of relevant previous tests for the concrete, e.g. from production or conformity control or from initial tests;
- g) strength development;
- h) sources of the constituents;
- i) D_{\max} .

(2) For the determination of curing time, information on the strength development of the concrete may be given either in terms of Table 16 or by a strength development curve at 20 °C between 2 and 28 days.

Table 16 — Strength development of concrete at 20 °C

| Strength development | Strength ratio $r = f_{cm,2} / f_{cm,28}$ |
|----------------------|--|
| Rapid | $\geq 0,5$ |
| Medium | $\geq 0,3$ to $< 0,5$ |
| Slow | $\geq 0,15$ to $< 0,3$ |
| Very slow | $< 0,15$ |

(3) The strength ratio to indicate the strength development is the ratio of the mean compressive strength after 2 days ($f_{cm,2}$) to the mean compressive strength after 28 days ($f_{cm,28}$), determined from initial tests or based on known performance of concrete of comparable composition. For these initial tests, specimens for strength determination shall be sampled, made, cured and tested in accordance with EN 12350-1, EN 12390-1, EN 12390-2 and EN 12390-3.

(4) The producer shall inform the user of health risks that may occur during handling the fresh concrete as required by the provisions valid in the place of use of the fresh concrete.

NOTE This standard does not require the information to be given in a specific format as this will depend on the relationship between the producer and the user, e.g. in the case of site-mixed concrete or precast concrete products, the producer and user of the concrete may be the same party.

7.3 Delivery ticket for ready-mixed concrete

(1) At delivery, the producer shall provide the user with a delivery ticket for each load of concrete on which is printed, stamped or written at least the following information:

- name of the ready-mixed concrete plant;
- serial number of ticket;
- date and time of loading, i.e. time of first contact between cement and water;
- truck number or vehicle identification;
- name of purchaser;

- name and location of the site;
- details or references to specifications, e.g. code number, order number;
- amount of concrete in cubic metres;
- declaration of conformity with reference to the specifications and to this European Standard;
- name or mark of the certification body if relevant;
- time at which the concrete arrives at the site;
- time of the beginning of unloading;
- time of the end of unloading.

(2) In addition, the delivery ticket shall give details of the following:

a) for designed concrete:

- strength class;
- exposure classes;
- chloride content class;
- consistence class or target value;
- limiting values of concrete composition, if specified;
- type and strength class of cement, if specified;
- type of admixture and addition, if specified;
- type and content of fibres or performance class of fibre reinforced concrete, if specified;
- special properties, if required;
- D_{\max} ;
- in case of lightweight or heavy-weight concrete: density class or target density.

b) for prescribed concrete:

- details of the composition, e.g. cement content, and, if required, type of admixture;
- either target w/c ratio, or consistence in terms of class or target value, as specified;
- D_{\max} ;
- type and content of fibres, if specified.

(3) In the case of standardized prescribed concrete, the information to be given shall follow the provisions of the relevant standard.

7.4 Delivery information for site-mixed concrete

(1) Appropriate information as required in 7.3 for the delivery ticket is also relevant for site-mixed concrete where the site is large or several types of concrete are involved or where the party producing the concrete is different from the party who is responsible for placing the concrete.

7.5 Mix adjustments after the main mixing process and prior to discharge

(1) In general, the adjustment of the mix proportions after the main mixing process is not allowed.

(2) In special cases, admixtures, pigments, fibres or water may be added where:

- this is under the responsibility of the producer;
- the consistence and the limiting values conform to the specified values; and
- there is a documented procedure for undertaking this process in a safe manner within the factory production control.

(3) Furthermore, if water is added, a conformity control shall be carried out on a sample of the final product.

(4) The quantity of any water, admixtures, pigments or fibres (if the content of fibres is specified), added to the truck mixer shall be recorded on the delivery ticket in all cases. For re-mixing, see 9.8.

NOTE For further information see Annex L, line 15.

8 Conformity control and conformity criteria

8.1 General

(1) Conformity control comprises the combination of actions and decisions to be taken in accordance with conformity rules adopted in advance to check the conformity of the concrete with the specification of concrete. Conformity control is an integral part of production control (see Clause 9).

NOTE The properties of concrete used for conformity control are those measured by the appropriate tests using standardized procedures. The actual values of the properties of the concrete in the structure may differ from those determined by the tests depending on, e.g. dimensions of the structures, placing, compaction, curing and environment.

(2) The sampling and testing plan and conformity criteria shall conform to the procedures given in 8.2 or 8.3. These provisions apply also to concrete for precast products unless the specific product standard contains an equivalent set of provisions. If higher sampling rates are required by the specifier, this shall be agreed in advance. For properties not covered in these clauses, the sampling and testing plan, method of test and conformity criteria shall be agreed upon between the producer and the specifier.

(3) The place of sampling for conformity tests shall be chosen such that the relevant concrete properties and concrete composition do not change significantly between the place of sampling and the place of delivery. In the case of lightweight concrete produced with unsaturated aggregates, the samples shall be taken at the place of delivery.

(4) Where tests for production control are the same as those required for conformity control, they shall be permitted to be taken into account for the evaluation of conformity. The producer may also use other test data on the delivered concrete in the conformity assessment.

(5) The conformity or non-conformity is judged against the conformity criteria. Non-conformity may lead to further action at the place of production and on the construction site (see 8.4).

8.2 Conformity control for designed concrete

8.2.1 Conformity control for compressive strength

8.2.1.1 General

(1) For normal-weight and heavy-weight concrete of strength classes from C8/10 to C55/67 or lightweight concrete from LC8/9 to LC55/60, sampling and testing shall be performed either on individual concrete compositions or on concrete families of established suitability as determined by the producer unless agreed otherwise. The family concept shall not be applied to concrete with higher strength classes. Lightweight concrete shall not be mixed into families containing normal-weight concrete. Lightweight concrete with demonstrably similar aggregates may be grouped into its own family.

NOTE For guidance for the selection of concrete families, see Annex K. More detailed information for the application of the concrete family concept is given in CEN/TR 16369 and CEN Report CR 13901.

(2) In the case of concrete families, the producer shall achieve control over all family members and sampling shall be carried out across the whole range of concrete compositions produced within the family.

(3) Where conformity testing is applied to a concrete family, a reference concrete is selected which is either that most commonly produced or one from the mid-range of strength classes of the concrete family. Relationships are established between each individual concrete composition of the family and the reference concrete in order to be able to transpose test results for compressive strength from each individual concrete test result to the reference concrete. The relationships shall be reviewed on the basis of original compressive strength test data at every assessment period and when there are appreciable changes in the production conditions. In addition, when assessing conformity for the family, it has to be confirmed that each individual member belongs to the family (see 8.2.1.3).

(4) In the sampling and testing plan and the conformity criteria of individual concrete compositions or concrete families, distinction is made between initial production and continuous production.

(5) Initial production covers the production until at least 35 test results are available.

(6) Continuous production is achieved when at least 35 test results are obtained over a period not exceeding 12 months.

(7) If the production of an individual concrete composition, or a concrete family, has been suspended more than 12 months, the producer shall adopt the criteria, sampling and testing plan given for initial production.

(8) During continuous production, the producer may adopt the sampling and testing plan and the criteria for initial production.

(9) If the strength is specified for a different age, the conformity is assessed on specimens tested at the specified age.

(10) Where identity of a defined volume of concrete with a population verified as conforming to the characteristic strength requirements is to be assessed, this shall be in accordance with Annex B.

8.2.1.2 Sampling and testing plan

(1) Samples of concrete shall be randomly selected and taken in accordance with EN 12350-1. Sampling shall be carried out on individual concrete compositions or on each family of concrete produced under conditions that are deemed to be uniform. The minimum rate of sampling and testing of concrete shall be in accordance with Table 17 at the rate that gives the highest number of samples for initial or continuous production, as appropriate.

(2) Notwithstanding the sampling requirements in 8.1, the samples shall be taken after any water or admixtures are added to the concrete under the responsibility of the producer, but sampling before adding plasticiser or superplasticiser to adjust the consistence (see 7.5) is permitted where there is proof by initial

testing that the plasticiser or superplasticiser in the quantity to be used has no negative effect on the strength of the concrete.

(3) The test result shall be that obtained from an individual specimen or the average of the results when two or more specimens made from one sample are tested at the same age.

(4) Where two or more specimens are made from one sample and the range of the test values is more than 15 % of the mean then the results shall be disregarded unless an investigation reveals an acceptable reason to justify disregarding an individual test value.

Table 17 — Minimum rate of sampling for assessing conformity

| Production | Minimum rate of sampling | | |
|---|---------------------------------------|---|--|
| | First 50 m ³ of production | Subsequent to first 50 m ³ of production ^a , the highest rate given by: | |
| | | Concrete with production control certification | Concrete without production control certification |
| Initial (until at least 35 test results are obtained) | 3 samples | 1 per 200 m ³ or 1 per 3 production days ^d | 1 per 150 m ³ or 1 per production day ^d |
| Continuous ^b (when at least 35 test results are available) | --- | 1 per 400 m ³ or 1 per 5 production days ^{c, d} or 1 per calendar month | |
| ^a Sampling shall be distributed throughout the production and should not be more than 1 sample within each 25 m ³ . ^b Where the standard deviation of the last 15 or more test results exceeds the upper limits for s_n according to Table 19, the sampling rate shall be increased to that required for initial production for the next 35 test results. ^c Or if there are more than 5 production days within 7 consecutive calendar days, once per calendar week. ^d The definition of a 'production day' shall be stated in provisions valid in the place of use. | | | |

8.2.1.3 Conformity criteria for compressive strength

8.2.1.3.1 Criteria for individual results

(1) Conformity of concrete compressive strength is assessed on specimens tested at 28 days in accordance with 5.5.1.2. Each individual test result, f_{ci} , shall satisfy:

$$f_{ci} \geq (f_{ck} - 4) \text{ N/mm}^2 \quad (1)$$

NOTE If the strength is specified for a different age, the conformity is assessed on specimens tested at the specified age.

8.2.1.3.2 Criteria for mean results

(1) The achievement of the specified characteristic strength shall be assessed by one of the following methods.

Method A: Initial production

(2) For initial production, the mean strength of non-overlapping or overlapping groups of three consecutive results shall satisfy:

$$f_{cm} \geq (f_{ck} + 4) \text{ N/mm}^2 \quad (2)$$

NOTE 1 The conformity criteria are developed on the basis of non-overlapping test results. Application of the criteria to overlapping test results increases the risk of rejection.

Method B: Continuous production

(3) Method B is an option when conditions of continuous production are established.

(4) Conformity assessment shall be made on test results taken during an assessment period that shall not exceed the period given by one of the following options depending on the rate of testing:

- for plants with lower testing rates (number of test results for designed concrete less than 35 per three months), the assessment period shall comprise at least 15 results and not more than 35 consecutive results taken over a period not exceeding 6 months;
- for plants with higher testing rates (number of test results for designed concrete 35 or more per three months) the assessment period shall comprise at least 15 consecutive results and not exceed three months.

(5) The mean strength of non-overlapping or overlapping groups of consecutive test results obtained from a single concrete or a concrete family in an assessment period shall satisfy:

$$f_{cm} \geq (f_{ck} + 1,48\sigma) \text{ N/mm}^2 \quad (3)$$

(6) Where this method is applied to a concrete family, the mean of all non-transposed test results (f_{cm}) for a single family member shall be assessed against the criterion given in Table 18. Any concrete failing this criterion shall be removed from the family and assessed individually for conformity.

(7) The removed concrete (or concretes) shall be assessed individually for conformity, using the conformity criteria established for initial production (Method A). The reintegration of the removed concretes is accepted, only after revision of the established relationships between the removed composition and the reference concrete.

Table 18 — Confirmation criterion for family members

| Number n of test results for compressive strength for a single family member | Mean of n results (f_{cm}) for a single family member N/mm ² |
|--|--|
| 2 | $\geq f_{ck} - 1,0$ |
| 3 | $\geq f_{ck} + 1,0$ |
| 4 | $\geq f_{ck} + 2,0$ |
| 5 | $\geq f_{ck} + 2,5$ |
| 6 | $\geq f_{ck} + 3,0$ |
| 7 to 9 | $\geq f_{ck} + 3,5$ |
| 10 to 12 | $\geq f_{ck} + 4,0$ |
| 13, 14 | $\geq f_{ck} + 4,5$ |
| ≥ 15 | $\geq f_{ck} + 1,48 \sigma$ |

NOTE 2 For guidance for the selection of concrete families, see Annex K.

(8) At the end of initial production, the standard deviation (σ) of the population shall be estimated from at least 35 consecutive test results taken over a period exceeding three months. When continuous production commences, this value of standard deviation shall be used to check the conformity over the first assessment period. At the end of the first and subsequent assessment periods, the standard deviation is checked to determine whether it has changed significantly using the limits given in Table 19. If it has not changed significantly, the current estimate of the standard deviation applies to the following assessment period. When there is a significant change in standard deviation, a new standard deviation is calculated from the most recent 35 consecutive results and applied to the following assessment period.

NOTE 3 For further information see Annex L, line 16.

Table 19 — Values for verification of standard deviation

| Number of test results | Limits for s_n |
|---|---|
| 15 to 19 | $0,63 \sigma \leq s_n \leq 1,37 \sigma$ |
| 20 to 24 | $0,68 \sigma \leq s_n \leq 1,31 \sigma$ |
| 25 to 29 | $0,72 \sigma \leq s_n \leq 1,28 \sigma$ |
| 30 to 34 | $0,74 \sigma \leq s_n \leq 1,26 \sigma$ |
| 35 ^a | $0,76 \sigma \leq s_n \leq 1,24 \sigma$ |
| ^a In case of more than 35 test results Formula (4) applies. | |

Method C: Use of control charts

(9) Method C is an option for assessing conformity by the use of control charts when conditions of continuous production are established and where the concrete production is covered by third party certification.

(10) The control system shall comprise the application of a recognised model of control chart and have the following characteristics:

- achieve a maximum average outgoing quality (AOQ) not exceeding 5,0 %;
- aim to ensure conformity of the relevant production with the required characteristic strength;
- include regular monitoring of strength and standard deviation or deviations from target values;
- where applicable, include one or more procedures for speeding the response of the system (e.g. use of early strength data, use of concrete families);
- define and apply clear decision rules for conformity and warning limits;
- when the control chart shows that the standard deviation is $\geq 0,5 \text{ N/mm}^2$ above the currently applied value, change the applied value.

NOTE 4 For further information see Annex L, line 17.

(11) One of the rules of application given in Annex H or in provisions valid in the place of use that meet the requirements of 8.2.1.3.2 (10) shall be applied.

NOTE 5 Annex H gives a method of application for cusum control charts and for Shewhart control charts with examples of conformity rules that achieve an average outgoing quality limit not exceeding 5,0 %. Guidance on values other than those given in Annex H are given in CEN/TR 16369, which for cusum control charts is based on [1].

8.2.2 Conformity control for tensile splitting strength

8.2.2.1 General

(1) 8.2.1.1 applies, but the concept of concrete families is not applicable. Each concrete composition shall be assessed separately.

NOTE For further information see Annex L line 18.

8.2.2.2 Sampling and testing plan

(1) 8.2.1.2 applies.

8.2.2.3 Conformity criteria for tensile splitting strength

(1) Where tensile splitting strength of concrete is specified, conformity assessment shall be made on test results taken during an assessment period that shall not exceed the period given by one of the following options depending on the rate of testing:

- for plants with lower testing rates (number of test results for designed concrete less than 35 per three months), the assessment period shall comprise at least 15 and not more than 35 consecutive results taken over a period not exceeding 6 months;
- for plants with higher testing rates (number of test results for designed concrete 35 or more per three months) the assessment period shall comprise at least 15 consecutive results and not exceed three months.

(2) Conformity of concrete tensile splitting strength is assessed on specimens tested at 28 days, unless a different age is specified in accordance with 5.5.1.3 for:

- groups of n non-overlapping or overlapping consecutive test results $f_{ctm,sp}$ (criterion 1);
- each individual test result $f_{cti,sp}$ (criterion 2).

(3) Conformity with the characteristic tensile splitting strength ($f_{ctk,sp}$) is confirmed if the test results satisfy both the criteria in Table 20 for either initial or continuous production as appropriate.

Table 20 — Conformity criteria for tensile splitting strength

| Production | Number n of results in the group | Criterion 1 | Criterion 2 |
|------------|------------------------------------|--|---|
| | | Mean of n results ($f_{ctm,sp}$) N/mm ² | Any individual test result ($f_{cti,sp}$) N/mm ² |
| Initial | 3 | $\geq f_{ctk,sp} + 0,5$ | $\geq f_{ctk,sp} - 0,5$ |
| Continuous | Not less than 15 | $\geq f_{ctk,sp} + 1,48 \sigma$ | $\geq f_{ctk,sp} - 0,5$ |

(4) The requirements for the standard deviation shall conform to 8.2.1.3.2, Method B.

8.2.3 Conformity control for properties other than strength

8.2.3.1 General

(1) Where other properties of concrete are specified, conformity assessments shall be made on the basis of individual loads for values for consistence, viscosity, passing ability, segregation resistance, air content and if

fibres are added at the truck mixer homogeneity of fibre distribution in fresh concrete as stated in Table 21. For the other properties, conformity assessments shall be made as stated in Table 22 on production over the assessment period that shall not exceed 6 months.

NOTE 1 Where identity testing is carried out for assessing that a defined volume of concrete belongs to a given population verified as conforming to the requirements for concrete consistence, air content of fresh concrete or the specified minimum value of fibre content, the procedure to be applied is given in Annex B.

NOTE 2 The conformity criteria for an individual batch and the identity testing criteria are the same.

8.2.3.2 Sampling and testing plan

(1) Batches for testing shall be randomly selected and the samples of concrete taken in accordance with EN 12350-1. Sampling shall be carried out on each family of concrete produced under conditions that are deemed to be uniform. The minimum number of samples and the methods of test shall be in accordance with Table 21 or Table 22 as appropriate.

8.2.3.3 Conformity criteria for properties other than strength

(1) Conformity with the required property is confirmed where both

- individual test results are within the maximum allowed deviation given in Tables 21 and 22 or the tolerances on target values conform to Table 23;
- and the number of test results for the property given in Table 22 outside the specified limiting value or class limits or tolerances on target values as appropriate is not greater than the acceptance number in Table 24; alternatively, the requirement may be based on testing by variables in accordance with ISO 3951-1 (AQL = 4 %).

(2) Where the batch has failed the individual criterion, this batch is declared as non-conforming and this result is excluded from any further consideration of conformity of the remaining concrete.

Table 21 — Conformity assessment for consistence classes, SCC properties, air content and homogeneity of fibre distribution of fresh concrete at the point of delivery

| Property | Test method or method of determination | Minimum number of samples or determinations | Maximum allowed deviation ^a at the point of delivery of single test results from limit values or for consistence the limits of the specified class | |
|--|--|---|---|-------------------------------|
| | | | Lower limit | Upper limit |
| Appearance | Comparison by visual inspection of the appearance of this concrete with its normal appearance | Each batch; for vehicle deliveries, each load | - | - |
| Slump | EN 12350-2 | i) Frequency as given in Table 17 for compressive strength ii) When testing air content iii) In case of doubt following visual inspection | -10 mm | +10 mm |
| Degree of compactibility | EN 12350-4 | | -20 mm ^b | +20 mm ^b |
| | | | -0,03 | +0,03 |
| Flow | EN 12350-5 | | -0,04 ^b | +0,04 ^b |
| | | | -10 mm -20 mm ^b | +10 mm +20 mm ^b |
| Slump flow | EN 12350-8 | If specified | No deviation allowed | No deviation allowed |
| Viscosity | EN 12350-8 or EN 12350-9 | | | |
| Passing ability | EN 12350-10 or EN 12350-12 | | | |
| Segregation resistance | EN 12350-11 | | | |
| Air content of air-entrained fresh concrete ^d | EN 12350-7 for normal-weight and heavy-weight concrete and ASTM C 173 for lightweight concrete | 1 sample / production day ^c | -0,5 % by volume | +5,0 % by volume |
| Homogeneous mixing of fibres in fresh concrete where the fibres are added at the truck mixer | As given in B.5 | Frequency ^c as given in Table 17 for compressive strength | As given in B.5 | |
| ^a Where there is no lower or upper limit in the relevant consistence class, these deviations do not apply. | | | | |
| ^b Only applicable for consistence testing from initial discharge from truck mixer or agitating equipment (see 5.4.1). | | | | |
| ^c Except where provisions valid in the place of use require higher minimum test rates. | | | | |
| ^d See 6.2.3 (1), fourth bullet point. | | | | |

Table 22 — Conformity assessment for fibre content, density, maximum water/cement ratio and minimum cement content

| Property | Test method or method of determination | Minimum number of samples or determinations | Acceptance number | Maximum allowed deviation of single test results from limit values, from tolerance on a target value or from the limits of the specified class | |
|--|--|---|-------------------|--|-----------------------|
| | | | | Lower limit | Upper limit |
| Steel fibre content of fresh concrete | See 5.4.4 | 1 determination per day | See Table 24 | -5 % by mass | No limit ^a |
| Polymer fibre content of fresh concrete | See 5.4.4 | 1 determination per day | See Table 24 | -10 % by mass | No limit ^a |
| Density of heavy-weight concrete | EN 12390-7 | As Table 17 for compressive strength | See Table 24 | -30 kg/m ³ | No limit ^a |
| Density of lightweight concrete | EN 12390-7 | As Table 17 for compressive strength | See Table 24 | -30 kg/m ³ | +30 kg/m ³ |
| Maximum Water/cement ratio, or Maximum Water/(cement + addition) ratio ^b , or Maximum Water/(cement + $k \times$ addition) ratio ^b | See 5.4.2 | 1 determination per day | See Table 24 | No limit ^a | +0,02 |
| Minimum cement content, or Minimum (cement + addition) content ^b , or Minimum (cement + $k \times$ addition) content ^b | See 5.4.2 | 1 determination per day | See Table 24 | -10 kg/m ³ | No limit ^a |
| ^a Unless limits are specified. ^b Depending on the addition concept in use, see 5.4.2. | | | | | |

Table 23 — Conformity criteria for target values ^a of consistence and viscosity

| Slump | | | |
|---|------------|--------------|--------|
| Target value in mm | ≤ 40 | 50 to 90 | ≥ 100 |
| Tolerance in mm | ± 10 | ± 20 | ± 30 |
| Degree of compactability | | | |
| Target value | ≥ 1,26 | 1,25 to 1,11 | ≤ 1,10 |
| Tolerance | ± 0,13 | ± 0,11 | ± 0,08 |
| Flow diameter | | | |
| Target value in mm | All values | | |
| Tolerance in mm | ± 40 | | |
| Slump flow diameter | | | |
| Target value in mm | All values | | |
| Tolerance in mm | ± 50 | | |
| t ₅₀₀ | | | |
| Target value in s | All values | | |
| Tolerance in s | ± 1 | | |
| t _v | | | |
| Target value in s | < 9 | ≥ 9 | |
| Tolerance in s | ± 3 | ± 5 | |
| a These values apply except where alternative values are given in Annex D or in provisions valid in the place of use. | | | |

Table 24 — Acceptance numbers for conformity criteria given in Table 22

| AQL = 4 % | |
|--|-------------------|
| Number of test results | Acceptance number |
| 1 to 12 | 0 |
| 13 to 19 | 1 |
| 20 to 31 | 2 |
| 32 to 39 | 3 |
| 40 to 49 | 4 |
| 50 to 64 | 5 |
| 65 to 79 | 6 |
| 80 to 94 | 7 |
| 95 to 100 | 8 |
| Where the number of test results exceeds 100, the appropriate acceptance numbers may be taken from ISO 2859-1:1999, Table 2-A. | |

8.3 Conformity control of prescribed concrete including standardized prescribed concrete

(1) Each batch or load of a prescribed concrete shall be assessed for conformity with the cement content, maximum size and proportions of aggregates if specified and, where relevant, water/cement ratio, quantity of admixture or addition. The amount of cement, aggregate (each specified size), admixture and addition as recorded in the production record or the printout from the batch recorder shall be within the tolerances on the specified values given in Table 27, and the water/cement ratio shall be within $\pm 0,04$ of the specified value.

(2) Where conformity of composition is to be assessed by analysis of fresh concrete, the test methods and conformity limits shall be agreed between the user and the producer in advance, taking account of the above limits and the precision of the test methods.

(3) Where conformity of the consistence is to be assessed, the relevant paragraphs of 8.2.3 and Table 21 and 24 apply.

(4) For the:

- cement type and strength class;
- types of aggregates;
- type of admixture, addition or fibre, if any;
- sources of concrete constituents, where specified,

the conformity shall be assessed by comparison of the production record and the delivery documents for the constituents with the specified requirements.

8.4 Actions in the case of non-conformity of the product

(1) The following actions shall be taken by the producer in the event of non-conformity:

- check test results and if invalid, take action to eliminate errors;
- if non-conformity is confirmed take corrective actions including a management review of relevant production control procedures;
- where there is confirmed non-conformity with the specification of concrete that was not obvious at delivery, give notice to the specifier(s) and user(s) in order to avoid any consequential damage;
- record actions on the items above.

(2) If non-conformity of concrete results from addition of water or admixtures on site (see 7.5), the producer has to take actions only if he has authorised this addition.

NOTE If the producer has given notice of non-conformity of the concrete or if the results of conformity tests do not fulfil the requirements, supplementary testing according to EN 12504-1 on cores taken from the structure or components can be required or a combination of tests on cores and non-destructive tests on the structure or components, e.g. according to EN 12504-2 or EN 12504-4. Guidance for assessing the strength in the structure or in structural components is given in EN 13791.

9 Production control

9.1 General

(1) All concrete shall be subject to production control under the responsibility of the producer.

(2) Production control comprises all measures necessary to maintain the properties of concrete in conformity to specified requirements. It includes:

- selection of constituents;
- concrete composition;
- concrete production;
- inspections and tests;
- the use of the results of tests on constituents, fresh and hardened concrete;
- calibration of equipment;
- where relevant, inspection of equipment used in transporting fresh concrete;
- conformity control for which provisions are given in Clause 8.

(3) The requirements for other aspects of production control are given in the following subclauses. These requirements shall be considered taking account of the kind and size of the production, the works, the particular equipment, procedures and rules in use at the place of production and use of the concrete. Additional requirements may be necessary for special circumstances at the production place or for specific requirements for particular structures or structural elements.

NOTE Clause 9 takes account of the principles of EN ISO 9001.

9.2 Production control systems

(1) The responsibility, authority and the interrelation of all personnel who manage, perform and verify work affecting the quality of the concrete shall be defined in a documented production control system (production control manual). This particularly concerns personnel who need the organisational freedom and authority to minimise the risk of non-conforming concrete and to identify and record any quality problem.

(2) The production control system shall be reviewed at least every two years by the management of the producer to ensure the suitability and effectiveness of the system. Records of such reviews shall be retained for at least three years unless legal obligations require a longer period.

(3) The production control system shall contain adequately documented procedures and instructions. These procedures and instructions shall, where relevant, be established in respect of the control requirements as given in the Table 28 and Table 29. The intended frequencies of tests and inspections by the producer shall be documented. The results of tests and inspections shall be recorded.

9.3 Recorded data and other documents

(1) All relevant data from the production control shall be recorded, see Table 25. The records of the production control shall be retained for at least three years unless legal obligations require a longer period.

Table 25 — Recorded data and other documents, where relevant

| Subject | Recorded data and other documents |
|---|--|
| Specified requirements | Contract specification or summary of requirements |
| Constituents | Name of suppliers, sources and declaration of performance |
| Tests on mixing water (not required for potable water) | Date and place of sampling Test results |
| Tests on constituents | Date and test results |
| Composition of concrete | Concrete description Record of masses of constituents in batch or load (e.g. cement content) Water/cement ratio Chloride content Code of family member |
| Tests on fresh concrete | Date and place of sampling Location in structure, if known Consistence (method used and results) Viscosity, if specified Segregation resistance, if specified Passing ability, if specified Density, if specified Fibre content, if specified Concrete temperature, if specified Air content, if specified Volume of concrete batch or load tested Number and codes of specimens to be tested Water/cement ratio, if specified |
| Tests on hardened concrete | Date of testing Code and ages of specimens Test results for density and strength Special remarks (e. g. unusual failure pattern of specimen) |
| Evaluation of conformity | Conformity/non-conformity with specifications of concrete |
| Additionally for ready-mixed concrete | Name of purchaser Location of work, e. g. the construction site Numbers and dates of delivery tickets related to tests Delivery tickets |
| Additionally for precast concrete | Additional or different data may be required by the relevant product standard |

9.4 Testing

(1) The testing shall be performed in accordance with the test methods given in this standard (reference test method) or other test methods may be used if the correlation or safe relationship between the results of these test methods and the reference methods have been established. The correctness of the safe relationship or correlation shall be examined at appropriate intervals. In case of dispute, the reference methods take precedence.

(2) The examination shall be carried out separately for each place of production which operates under different conditions, unless the relationship is given in provisions valid in the place of use.

9.5 Concrete composition and initial testing

(1) In the case of using a new concrete composition, initial testing shall be performed to provide a concrete that achieves the specified properties or intended performance with an adequate margin (see Annex A). Except for self-compacting concrete, initial testing is not required where long term experience with a similar concrete or family is available. The concrete design and design relationships shall be re-established when there is a significant change in constituents. No initial testing by the producer is necessary in the case of a prescribed concrete or a standardized prescribed concrete.

(2) New concrete compositions obtained by interpolation between known concrete compositions or extrapolations of compressive strength not exceeding 5 N/mm^2 are deemed to satisfy the requirements for initial testing.

(3) Concrete compositions shall be reviewed periodically to provide assurance that all concrete compositions are still in accordance with the actual requirements, taking account of the change in properties of the constituents and the results of conformity testing on the concrete compositions.

9.6 Personnel, equipment and installation

9.6.1 Personnel

(1) Knowledge, training and experience of personnel involved in production and production control shall be appropriate to the type of concrete, e.g. self-compacting concrete, lightweight concrete.

(2) Appropriate records of the training and experience of the personnel involved in production and production control shall be maintained.

NOTE In some countries, there are special requirements regarding the level of knowledge, training and experience for the different tasks.

9.6.2 Equipment and installation

9.6.2.1 Storage of constituents

(1) Constituents shall be stored and handled so that their properties do not change significantly, e.g. by action of climate, intermingling or contamination, and that the conformity with the respective standard is maintained.

(2) Storage compartments shall be clearly marked in order to avoid errors in use of the constituents.

(3) Special instructions from the suppliers of the constituents shall be taken into account.

(4) Facilities shall be provided to enable representative samples to be taken e.g. from stockpiles, silos and bins.

9.6.2.2 Batching equipment

(1) The performance of the batching equipment shall be such that under practical conditions of operation the tolerances stated in 9.7 can be obtained and maintained.

(2) The batching equipment shall conform to the requirements given in Table 26.

Table 26 — Requirements for batching equipment

| Where batching by mass | | |
|---|---|---|
| Load in % of the full scale | Minimum load ^a to 20 % Full scale | 20 % Full scale to maximum load ^a |
| Maximum permissible error in % of the load | ± 2 % | ± 1 % |
| Where batching by volume | | |
| Measured volume | < 30 l | ≥ 30 l |
| Maximum permissible error in % of the volume | ± 3 % | ± 2 % |
| ^a Minimum load and maximum load are provided by the manufacturer of the equipment. | | |

9.6.2.3 Mixers

(1) All mixers shall be capable of achieving a uniform distribution of the constituents, and a uniform consistence of the concrete within the mixing time and at the mixing capacity.

(2) Truck mixers and agitating equipment shall be so equipped as to enable the concrete to be delivered in a homogeneous state. In addition, the truck mixers shall be provided with suitable measuring and dispensing equipment, if water or admixtures are to be added on the site under the responsibility of the producer. If fibres are to be added to the truck mixer under the responsibility of the producer, suitable measuring and dispensing equipment shall be available at the place of adding the fibres.

9.6.2.4 Testing equipment

(1) All necessary facilities, equipment and instructions for its proper use shall be available when required for inspections and tests on equipment, constituents and concrete.

(2) Relevant test equipment shall be in calibration at the time of testing and the producer shall operate a calibration programme.

9.7 Batching of constituents

(1) A documented batching instruction giving details of the type and quantity of the constituents shall be available at the place of batching of the concrete.

(2) For quantities of concrete of 1 m³ or more, the tolerance of batching constituents shall not exceed the values given in Table 27 except where other tolerances are given in provisions valid in the place of use. Where a number of batches are mixed or re-mixed in a truck mixer, the tolerances in Table 27 apply to the load.

NOTE For further information see Annex L, line 19.

Table 27 — Tolerances for the batching process of constituents

| Constituent | Tolerance |
|---|----------------------------|
| Cement Water Total aggregates Additions and fibres used at > 5 % by mass of cement | ± 3 % of required quantity |
| Admixtures, additions and fibres used at ≤ 5 % by mass of cement | ± 5 % of required quantity |
| NOTE The tolerance is the difference between the target value and the measured value. | |

(3) Cements, normal-weight and heavy-weight aggregates and fibres as well as additions in the form of powders shall be batched by mass, except where other methods achieve the required batching tolerance and this is documented.

(4) The mixing water, lightweight aggregates, admixtures and additions in form of a slurry shall be batched by mass or by volume.

9.8 Mixing of concrete

(1) Mixing of the constituents shall be carried out in a mixer conforming to 9.6.2.3 and be continued until the concrete is homogeneous.

(2) Mixers shall not be loaded in excess of their rated mixing capacity.

(3) Where provision is made to add the constituents listed in 7.5 after the main mixing process, the concrete shall be re-mixed until the added constituent has been completely dispersed throughout the batch or load and, in the case of an admixture, has become fully effective.

NOTE For further information see Annex L, line 20.

(4) For lightweight concrete batched with unsaturated aggregates, the period from initial mixing to the end of final mixing (e.g. re-mixing in a truck mixer) shall be prolonged until the water absorption of the aggregates and subsequent evacuation of air from the lightweight aggregates does not have any significant negative impact on the hardened concrete properties.

(5) The composition of the fresh concrete shall not be altered after leaving the mixer.

9.9 Production control procedures

(1) The constituents, equipment, production procedures and concrete shall be controlled with regard to their conformity with the specifications of concrete and the requirements of this standard. The control shall be such that significant changes that influence the properties are detected and appropriate corrective action taken.

(2) A procedure shall be put in place to ensure the correct delivery, storage and use of constituents including:

- checking that the delivered material is what was ordered;
- checking that it is being discharged into the correct location;
- preventing discharge of any materials that are clearly non-conforming;
- storing materials in a way that minimises the risk of contamination or deterioration;
- keeping records of deliveries;
- testing of suspect deliveries for all properties for which conformity with the relevant standard or other specification is in doubt;
- checks on the water content of the aggregates.

NOTE To produce consistent self-compacting concrete, it is essential to have constituent materials with consistent properties. These properties might need to be monitored more frequently than for ordinary concrete.

(3) If a concrete producer produces its own aggregates, the concrete producer shall be regarded as an aggregate producer and shall comply with the technical aspects of the relevant European aggregate standard.

(4) The control of equipment shall ensure that the storage facilities, the weighing and gauging equipment, the mixer and control apparatus (e.g. the measuring of water content of the aggregates) are in good working

condition and that they conform to the requirements of this standard. Frequency of inspections and tests for equipment (where used) are given in Table 28.

(5) Plant, equipment and transport facilities shall be subject to a planned maintenance system and shall be maintained in efficient working condition so that the properties and the quantity of concrete are not adversely affected.

(6) The properties of designed concrete shall be controlled to the specified requirements as given in Table 29.

(7) The proportions of prescribed concrete, its consistence and temperature, where specified, shall be controlled to the specified requirements as given in Table 29 where the rows are relevant for prescribed concrete.

(8) The control shall include production, transport to the point of delivery and delivery.

(9) For some concretes, additional requirements for production control may be necessary. These are not defined in the standard. If the contract has defined special requirements for the concrete, the production control shall include appropriate actions in addition to those in Table 29.

(10) The actions foreseen in Tables 28 and 29, in special cases, may be adapted to the conditions of the specific production place and be replaced by actions which provide an equivalent level of control.

Table 28 — Equipment control

| | Equipment | Inspection/test | Purpose | Minimum frequency |
|---|---|---|---|--|
| 1 | Stockpiles, bins, etc | Visual inspection | To ascertain conformity with the requirements | Once per week |
| 2 | Weighing equipment | Visual inspection of the performance | To ascertain that the weighing equipment is in a clean condition and functions correctly | Daily |
| 3 | | Test of weighing equipment | To meet the requirements of 9.6.2.2 | On installation Periodically ^a depending on provisions valid in the place of use In case of doubt |
| 4 | Admixtures dispenser (including those mounted on truck mixers) | Visual inspection of performance | To ascertain that the measuring equipment is in a clean condition and functions correctly | First use of the day for each admixture |
| 5 | | Test of measuring equipment and completion of discharge | To meet the requirements of 9.6.2.2 | On installation Periodically ^a after installation In case of doubt |
| 6 | Water meter and water dispenser mounted on truck mixer | Test of measuring equipment | To meet the requirements of 9.6.2.2 | On installation Periodically ^a after installation In case of doubt |
| 7 | Equipment for continuous measurement of water content of aggregates | Comparison of the actual amount with the reading of the meter | To ascertain correct values | On installation Periodically ^a after installation In case of doubt |
| 8 | Batching system | Visual inspection | To ascertain that the batching equipment is functioning correctly | Daily |
| 9 | | Comparison (by a suitable method depending on the batching system) of the actual mass of the constituents in the batch with the target mass and in the case of automatic batch recording with the recorded mass | To meet the requirements of 9.7 | On installation In case of doubt Periodically ^a after installation |
| 10 | Testing apparatus | Calibration according to relevant national or EN standards | To check the conformity | Periodically ^a For strength testing apparatus, at least once per year |
| 11 | Mixers (including truck mixers) | Visual inspection | To check the wear of the mixing equipment | Periodically ^a |
| ^a The frequency depends on the kind of equipment, its sensitivity in use and the production conditions of the plant. | | | | |

Table 29 — Control of production procedures and of concrete properties (1 of 2)

| | Type of test | Inspection/ test | Purpose | Minimum frequency |
|----|--------------------------------------|--|--|--|
| 1 | Properties of designed concrete | Initial test (see Annex A) | To provide proof that specified properties are met by the proposed composition with an adequate margin | Before using a new concrete composition |
| 2 | Water content of fine aggregates | Continuous measuring system, drying test or equivalent | To determine the dry mass of aggregate and the water to be added | If not continual, daily, depending on local and weather conditions more or less frequent tests may be required |
| 3 | Water content of coarse aggregates | Drying test or equivalent | To determine the dry mass of aggregate and the water to be added | Depending on local and weather conditions |
| 4 | Water content of fresh concrete | Check of the quantity of water added ^b | To provide data for the water/cement ratio | Every batch or load |
| 5 | Chloride content of concrete | Initial determination by calculation | To ensure that the maximum chloride content is not exceeded | When performing initial test In case of an increase in the chloride content of the constituents |
| 6 | Consistence | Visual inspection | For comparison with normal appearance | Every batch or load |
| 7 | | Consistence test according to EN 12350-2, EN 12350-4 or EN 12350-5 | To assess the achievement of the specified values of consistence and to check e.g. possible changes of water content | Where consistence is specified, as Table 17 for compressive strength When testing air content In case of doubt following visual inspections |
| 8 | | Consistence test according to EN 12350-8 | | At least once a day When testing compressive strength (same frequency) When testing air content In case of doubt following visual inspections |
| 9 | Viscosity of concrete | EN 12350-8 or EN 12350-9 | To assess the achievement of the declared values of consistence | When performing initial test |
| 10 | Passing ability | EN 12350-10 or EN 12350-12 | | Before using a new concrete composition |
| 11 | Segregation resistance | EN 12350-11 | | In case of a change in the constituents In case of doubt following visual inspections or slump-flow test |
| 12 | Density of fresh concrete | Density test according to EN 12350-6 | For lightweight and heavy-weight concrete for supervision of batching and density control | Daily |
| 13 | Cement content of fresh concrete | Check the mass of cement batched ^b | To check the cement content and to provide data for the water/cement ratio | Every batch or load |
| 14 | Additions content of fresh concrete | Check the mass of additions batched ^b | To check the additions content and to provide data for the w/c ratio (see 5.4.2) | Every batch or load |
| 15 | Admixture content of fresh concrete | Check the mass or volume of admixture batched ^b | To check the admixture content | Every batch or load |
| 16 | Water/cement ratio of fresh concrete | By calculation or by test method, see 5.4.2 | To assess the achievement of the specified water/cement ratio | Daily, where specified |

Table 29 (2 of 2)

| | Type of test | Inspection/ test | Purpose | Minimum frequency |
|--|---|--|---|---|
| 17 | Air content of fresh concrete where specified | Test according to EN 12350-7 for normal- weight and heavy-weight concrete ASTM C 173 for lightweight concrete | To assess the achievement of the specified content of entrained air | For concretes containing entrained air: first batches or loads of each production day until values stabilise |
| 18 | Temperature of fresh concrete | Measure temperature | To assess the achievement of the minimum temperature of 5 °C or specified limit | In case of doubt Where temperature is specified: – periodically, dependent on the situation; – each batch or load where the concrete temperature is close to the limit |
| 19 | Density of hardened light-weight or heavy-weight concrete | Test according to EN 12390-7 ^a | To assess the achievement of the specified density | Where density is specified, as frequently as compressive strength test |
| 20 | Compressive strength test on moulded concrete specimen | Test according to EN 12390-3 | To assess the achievement of the specified strength | Where compressive strength is specified, as frequently as for conformity control, see 8.1 and 8.2.1 |
| ^a May also be tested in saturated conditions, where correlation to oven-dry density is established. ^b Where recording equipment is not used and the batching tolerances for the batch or load are exceeded, record the batched quantity in the production record. | | | | |

10 Evaluation of conformity

10.1 General

(1) The producer is responsible for the evaluation of conformity for specified requirements of the concrete. For this purpose, the producer shall carry out the following tasks:

- a) initial tests, when required (see 9.5 and Annex A);
- b) production control (see Clause 9), including conformity control (see Clause 8).

(2) Whether accredited inspection and certification bodies are recommended to inspect the production control and certify its conformity depends on the level of performance requirements for the concrete, its intended use, the kind of production and the margin of safety in the concrete composition.

(3) In general, the inspection and certification of the production control by accredited inspection and certification bodies is recommended. This is not considered to be necessary for standardized prescribed concrete with a high margin of safety in the composition (see A.5).

(4) For precast concrete products, the requirements and provisions for the evaluation of conformity are given in the relevant technical specifications (product standards and technical approvals).

10.2 Assessment, surveillance and certification of production control

(1) Where it is required either in a contract or by provisions valid in the place of use of the concrete, that the producer's production control shall be assessed and surveyed by an accredited inspection body and then

certified by an accredited certification body, the provisions for assessment, surveillance and certification given in Annex C apply.

11 Designation for designed concrete

(1) Where the essential characteristics of designed concrete are to be given in an abbreviated form, the following format shall be applied:

- reference to this European Standard: EN 206;
- compressive strength class: compressive strength class as defined in Table 12 or Table 13, e.g. C25/30;
- exposure class(es): class designation(s) defined in Table 1. If the concrete is exported the exposure class(es) followed by the abbreviation of the country name²⁾ that issued the provisions for the limiting values, concrete composition and concrete properties or other set of requirements, e.g. XD2(F) where the French provisions apply;
- maximum chloride content: the class defined in Table 15, e.g. Cl 0,20;
- declared value of the coarsest fraction of aggregate actually used in the concrete: the value of D_{\max} , e.g. $D_{\max} 22$;
- density: the class designations as given in Table 14 or the target value, e.g. D1,8;
- consistence: by class as defined in 4.2.1 or by a target value and method.

2) In accordance with the internationally recognized car plate code. To the abbreviation of the country name, further information concerning the provisions may be added.

Annex A **(normative)**

Initial test

A.1 General

(1) This annex provides details of initial testing as required in 5.2.5.1, 6.1 and 9.5.

(2) The initial test shall establish a concrete composition that satisfies all specified requirements for fresh and hardened concrete. Where the producer or specifier can demonstrate an adequate concrete composition, based on data from previous tests or long-term experience, this may be considered as an alternative to initial tests.

A.2 Party responsible for initial tests

(1) Initial tests shall be the responsibility of the producer for designed concrete, the specifier for prescribed concrete and the standardization body for standardized prescribed concrete.

A.3 Frequency of initial tests

(1) Initial tests shall be performed before using a new concrete or concrete family.

(2) Initial tests shall be repeated if there has been a significant change either in the constituent materials or in the specified requirements on which the previous tests were based.

A.4 Test conditions

(1) In general, initial tests shall be carried out on fresh concrete with a temperature of 15 °C to 22 °C.

NOTE 1 For further information see Annex L, line 21.

(2) For the initial test of a single concrete, at least three specimens from each of three batches shall be tested. Where the initial test is for a concrete family, the number of concretes to be sampled shall encompass the composition range of the family. In this case, the number of batches per concrete may be reduced to one.

(3) The strength of a batch or load shall be taken to be the average of the test results. The result of the initial test on the concrete is the average strength of the batches or loads.

(4) The time between mixing and consistence testing and the test results shall be recorded.

(5) A significantly higher number of tests are necessary for prescribing the composition of a standardized prescribed concrete to encompass all the permitted constituent materials, which are foreseen to be used on a national level. The results of the initial tests shall be documented at the responsible standard organisation.

(6) Where concrete containing fibres is to be produced, the initial testing shall verify that the producers documented procedure achieves a homogenous distribution of the fibres throughout the batch. This requirement is satisfied if the test results conform to the criteria given in B.5 and the batched fibre content is the same as the specified fibre content.

(7) In case of self-compacting concrete, initial tests shall include a study of mix design robustness regarding water content variations. This investigation is to determine the allowable range of water content within which fresh-state specifications (consistence, viscosity, passing ability and segregation resistance) are fulfilled.

(8) Where recovered water is to be used in the production of self-compacting concrete, initial tests shall demonstrate that fresh concrete properties are adequate, taking into account the variations of solid content and chemical analysis of recovered water at the intended place of production.

(9) Where concrete containing recycled aggregates is to be produced, the need to carry out tests to determine the drying shrinkage, creep and modulus of elasticity shall be considered.

NOTE For further information see Annex L, line 22.

A.5 Criteria for adoption of initial tests

(1) For assessing the properties of concrete, in particular those of fresh concrete and, where relevant, the distribution of air voids for hardened concrete, the differences between the type of mixer and mixing procedure applied during the initial test and those applied during actual production shall be taken into account.

(2) The compressive strength of the concrete with the composition to be adopted for the actual case shall exceed the values f_{ck} of Table 12 or Table 13 by an adequate margin. The margin should be about twice the expected standard deviation, which means at least a margin of 6 N/mm² to 12 N/mm² depending on the production facilities, the constituent materials and the available background information about the variation.

(3) The criterion for adoption of initial tests for standardized prescribed concrete is:

$$f_{cm} \geq f_{ck} + 12 \quad (\text{A.1})$$

(4) The consistence of the concrete shall be within the limits of the consistence class at the time at which the concrete is likely to be placed or delivered in the case of ready-mixed concrete.

(5) For self-compacting concrete, initial tests shall demonstrate that in the permitted slump-flow range the concrete composition maintains the declared properties in terms of viscosity, passing ability and segregation resistance.

(6) For other properties that are specified, the concrete shall meet the specified values with an appropriate margin.

Annex B **(normative)**

Identity testing

B.1 General

(1) This annex provides details for identity testing as indicated in 8.2.1.1 and 8.2.3.1.

(2) Identity testing indicates whether the defined volume of concrete under review belongs to the same population as that verified as conforming via conformity assessment by the producer.

B.2 Sampling and testing plan

(1) Where identity testing is to be performed, the particular volume of concrete shall be defined, e.g.:

- single batch or load where there is doubt as to the quality;
- the concrete supplied for each storey of a building or group of beams/slabs or columns/walls of a storey of a building or comparable parts of other structures;
- the concrete delivered to a site within one week, but not more than 400 m³.

(2) The number of samples to be taken from a particular volume of concrete shall be defined.

(3) Samples shall be taken from different batches or loads in accordance with EN 12350-1.

(4) Test specimens for compressive strength testing shall be prepared and cured in accordance with EN 12390-2. The compressive strength of the specimens shall be determined in accordance with EN 12390-3. The test result shall be that obtained from the average of the results of two or more specimens made from one sample for testing at the same age. Where the range of the test values is more than 15 % of the mean, the results shall be disregarded unless an investigation reveals an acceptable reason to justify disregarding an individual test value.

(5) Consistence, air content of fresh concrete, viscosity, passing ability and segregation resistance shall be tested in accordance with Table 21.

B.3 Identity criteria for compressive strength

B.3.1 Concrete under production control certification

(1) Identity of concrete is assessed for each individual strength test result and the average of n non-overlapping discrete results.

(2) Concrete is deemed to come from a conforming population if both the criteria in Table B.1 are satisfied for n results derived from strength tests on samples taken from the defined volume of concrete.

Table B.1 — Identity criteria for compressive strength

| Number n of test results for compressive strength from the defined volume of concrete | Criterion 1 | Criterion 2 |
|---|--|---|
| | Mean of n results (f_{cm}) N/mm ² | Any individual test result (f_{ci}) N/mm ² |
| 1 | Not applicable | $\geq f_{ck} - 4$ |
| 2 to 4 | $\geq f_{ck} + 1$ | $\geq f_{ck} - 4$ |
| 5 to 6 | $\geq f_{ck} + 2$ | $\geq f_{ck} - 4$ |

NOTE The identity criteria of Table B1 give a probability of 1 % that a conforming concrete volume is rejected.

B.3.2 Concrete not under production control certification

(1) At least three samples shall be taken for testing from the defined volume of concrete.

(2) The concrete is deemed to come from a conforming population if the conformity criteria in 8.2.1.3 for initial production are satisfied.

B.4 Identity criteria for consistence and air content

(1) Identity of concrete is assessed for each individual test result as stated in Table 21. Concrete is deemed to come from a conforming population if the criteria in Table 21 are satisfied for each individual test result derived from tests on samples taken from the defined volume of concrete.

B.5 Identity criteria for fibre content and homogeneity of fresh concrete

(1) The test procedure for steel fibre content and homogeneity shall be in accordance with EN 14721 using three samples per load. The test procedure (excluding sampling) for class II polymer fibre content and homogeneity shall be in accordance with EN 14488-7. For class Ia and class Ib polymer fibres test methods valid in the place of use shall be used. In all cases, three samples per load shall be taken during unloading from the first, middle and last third of the load.

(2) Concrete is deemed to come from a conforming population if both criteria in Table B.2 are satisfied.

Table B.2 — Combined Identity criteria for fibre content and homogeneity of fresh concrete

| Applicable to | Criterion |
|----------------------------------|--|
| Every sample | $\geq 0,80$ of the specified minimum value |
| Average of 3 samples from a load | $\geq 0,85$ of the specified minimum value |

Annex C **(normative)**

Provisions for assessment, surveillance and certification of production control

C.1 General

(1) Where required for the production control (see Clause 9), the provisions for assessment, surveillance and certification of production control by an accredited body are given in this annex.

C.2 Tasks for the inspection body

C.2.1 Initial assessment of the production control

(1) An initial inspection of the concrete plant and its production control shall be performed by the accredited inspection body. The initial inspection is for the purpose of determining whether the prerequisites, in terms of staff and equipment for orderly production and for the corresponding production control, appear to be suitable.

(2) The inspection body shall check at least:

- the producer's production control manual and assess the provisions of it and in particular whether it conforms with the requirements for production control in Clause 9 and whether it takes account of the requirements of this standard;
- the availability of current documents essential for plant inspections at the relevant places and if these are available to the relevant persons;
- if all necessary facilities and equipment are available to carry out the necessary inspections and tests on equipment, constituent materials and concrete;
- the knowledge, training and experience of the staff for production and production control;
- if initial testing is performed according to Annex A of this standard and if this is reported in an adequate manner.

(3) If indirect testing is performed or if conformity for strength is based on the transposed results of the family concept, the producer shall prove the correlation or safe relationship between the direct and indirect testing to the satisfaction of the inspection body.

(4) To provide confidence in the results of the production control, the inspection body shall perform spot tests in parallel to those of the producer's. Such testing may be replaced by an in-depth surveillance of the producer's data and control system where the producer's testing laboratory is accredited and under the surveillance of an accreditation body.

(5) All the relevant facts from the initial inspection, especially the equipment at the production place, the production control system and the assessment of the system, shall be documented in an assessment report.

(6) When a production unit has passed the initial inspection to the satisfaction of the inspection body, the inspection body shall issue an assessment report that the production control conforms to Clause 9 of this standard. This report shall be passed to the producer and to the accredited certification body.

NOTE On the basis of this report, the accredited certification body will decide on the certification of the production control (see C.3.1).

C.2.2 Continuous surveillance of the production control

C.2.2.1 Routine inspection

(1) The principal objective of the routine inspection by the inspection body is to check whether the prerequisites for production and agreed production control are being maintained. For this purpose, the assessment report of the initial inspection is used as a statement of the agreed production control.

(2) The producer is responsible for the maintenance of the production control system. When significant changes are made at the facilities at the production place, to the production control system or to the production control manual, the producer shall notify the changes to the inspection body which may request a re-inspection.

(3) During the routine inspection, the inspection body shall assess at least:

- the production, sampling and testing procedures;
- the recorded data;
- the test results obtained for production control during the inspection period;
- that the required tests or procedures have been carried out with appropriate frequency;
- that the production equipment has been checked and maintained as scheduled;
- that the test equipment has been maintained and calibrated as scheduled;
- the actions taken with respect to any non-conformity;
- the delivery tickets and the declarations of conformity, where relevant.

(4) To provide confidence in the sampling and testing of the producer's production control, the inspection body shall, during the routine inspection, take spot samples from the running production for testing. Sampling for this purpose shall not be announced in advance. The inspection body shall determine the appropriate frequency for each production unit, in which testing on the concrete should be conducted, taking account of the individual circumstances. Such testing may under special individual circumstances be replaced by an in-depth surveillance of the producer's data and control system when the producer's testing laboratory is accredited and under the surveillance of the accreditation body.

(5) Designed concretes shall be tested for the specified properties, e.g. strength, consistence. For prescribed concrete, testing shall cover consistence and composition only.

(6) Comparison shall be made between the producer's routine test results and the results of testing by the inspection body.

(7) The inspection body shall periodically examine the safe relationship between the direct and indirect testing and the relationships between the members of a concrete family.

(8) The results of the routine inspection shall be documented in a report to be passed to the producer and the certification body.

(9) The routine inspections shall be performed, at least, twice a year, except where the verification or the certification scheme defines conditions for decreasing or increasing that frequency.

C.2.2.2 Extraordinary inspections

(1) An extraordinary inspection is necessary:

- if severe discrepancies are detected during a routine inspection (re-inspection);
- when there has been no production for a period of more than six months;
- where requested by the producer, e. g. because of changes in the production conditions;
- if requested by the certification body, giving due justification.

(2) The scope, type and timing of the extraordinary inspection depends on the particular situation.

C.3 Tasks for the certification body

C.3.1 Certification of production control

(1) The certification body shall certify the production control on the basis of a report from the inspection body that states the production unit has passed the initial assessment of the production control to the satisfaction of the inspection body.

(2) The certification body shall decide on the further validity of the certificate on the basis of the reports of the continuous surveillance of the production control.

C.3.2 Measures in case of non-conformity

(1) Where the inspection body identifies non-conformity with the specification of concrete or where defects have been revealed in the production process or in the production control on which the producer has not reacted properly in due time (see 8.4), the certification body shall request the producer to rectify the defects within an appropriately short period. The actions of the producer shall be verified by the inspection body.

(2) If appropriate, an extraordinary inspection and additional tests shall be arranged in the case of non-conformity with:

- strength;
- water/cement ratio;
- basic limits on the composition;
- performance class of fibre reinforced concrete;
- density for designed light-weight and heavy-weight concrete;
- specified composition in the case of prescribed concrete.

(3) If the results of the extraordinary inspection are not satisfactory or if the additional tests failed the set criteria, the certification body shall suspend or withdraw the certificate of conformity of the production control without undue delay.

NOTE After the suspension or the withdrawal of the certificate of conformity of the production control, the producer is no longer permitted to refer to the certificate.

(4) In case of other faults, the certification body may consider an extraordinary inspection unnecessary and may accept documentary evidence that the fault has been rectified. Such evidence shall be confirmed during the next routine inspection.

Annex D (normative)

Additional requirements for specification and conformity of concrete for special geotechnical works

D.1 General

(1) This annex provides additional requirements for the specification and conformity of concrete used in:

- bored piles constructed in accordance with EN 1536;
- diaphragm walls constructed in accordance with EN 1538;
- cast-in-place displacement piles constructed in accordance with EN 12699;
- micropiles constructed in accordance with EN 14199.

NOTE 1 This annex is the result of the inclusion of the normative rules for concrete for special geotechnical works which were hitherto given in EN 1536, EN 1538, EN 12699 and EN 14199 into this standard aiming a harmonisation of the system for rules for specification and conformity of concrete which is used in the execution of various concrete works.

(2) The requirements provided in this annex have to be specified in accordance with 6.2.

(3) For the applications listed above, the specific provisions of Annex D shall prevail.

NOTE 2 For special geotechnical works provisions on cements, minimum cement content, minimum fines content, maximum water/cement ratio, target values of consistence and maximum tolerances for target values can deviate from the provisions for other works.

D.2 Constituents

D.2.1 Cement

(1) The cement shall conform to the provisions valid in the place of use for the specified exposure classes and shall have established suitability for use in the geotechnical applications covered in this annex.

(2) Cement shall be of the following types as defined in EN 197-1 or be a type permitted under (3):

- Portland cement CEM I;
- Portland-slag cement CEM II/A-S and II/B-S;
- Portland-silica fume cement CEM II/A-D;
- Portland-pozzolana cement CEM II/A-P and II/B-P;
- Portland-fly ash cement CEM II/A-V and II/B-V;
- Portland-burnt shale cement CEM II/A-T and II/B-T;
- Portland-limestone cement CEM II/A-LL;
- Portland-composite cement CEM II/A-M (S-V) and CEM II/B-M (S-V);

- Portland-composite cements CEM II/A-M (S-LL, V-LL) and CEM II/B-M (S-LL, V-LL);
- Blast furnace cement CEM III/A, III/B and III/C.

(3) Cement types permitted in 5.1.2 but not listed in (2) may be used where the suitability for the use in the geotechnical applications covered by this annex is established in provisions valid in the place of use of the concrete.

D.2.2 Aggregates

(1) In order to minimise segregation, aggregates should be continuously graded, and round aggregates are preferred.

NOTE The use of recycled or porous aggregate can affect the consistence over time.

(2) The specified D_{upper} shall not exceed

- for bored piles and diaphragm walls: 32 mm and 1/4 of the clear space between the longitudinal bars,
 - for displacement piles: 32 mm and 1/3 of the clear space between the longitudinal bars,
 - for micropiles: 16 mm and 1/4 of the clear space between the longitudinal bars,
 - in the case of submerged placement: 1/6 of the internal diameter of the tremie or pumping pipe,
- whichever is the lowest.

(3) A D_{lower} shall be specified.

D.3 Concrete

D.3.1 General requirements for specification and acceptance of the mix design

(1) The concrete mix design shall satisfy the specification of concrete that shall take into account:

- the need for a high resistance against segregation;
- the need for adequate plasticity and good cohesiveness;
- the need of flowing well;
- the need to be able to compact adequately by gravity;
- the need of sufficient workability for the duration of the placement procedure, including the removal of any temporary casings.

NOTE The choice of cement and the use of additions can improve certain properties of the concrete.

(2) The proposed mix design shall be accepted prior to production.

D.3.2 Minimum fines content and minimum cement content

(1) For bored and cast-in-place displacement piles the minimum fines content and minimum cement content shall be specified in accordance with Table D.1:

Table D.1 — Minimum cement and fines content for concrete for bored piles and cast-in-place displacement piles

| | | |
|--|--|---------------------------|
| Cement content: | | |
| placement in dry conditions | | $\geq 325 \text{ kg/m}^3$ |
| placement in submerged conditions (under water or support fluids) | | $\geq 375 \text{ kg/m}^3$ |
| Fines content ^a | | |
| coarse aggregate | $D_{\text{lower}} > 8 \text{ mm}$ $D_{\text{upper}} > 8 \text{ mm}$ | $\geq 400 \text{ kg/m}^3$ |
| coarse aggregate | $D_{\text{lower}} \geq 4 \text{ mm}$ $D_{\text{upper}} \leq 8 \text{ mm}$ | $\geq 450 \text{ kg/m}^3$ |
| ^a Fines: Particle sizes $\leq 0,125 \text{ mm}$ (including additions and cement). | | |

(2) For semi-dry concrete which is tamped during the installation of cast-in-place displacement piles the cement content shall be specified with a minimum of 350 kg/m^3 and the strength class shall be at least C25/30.

(3) For micropiles, the minimum fines and cement content shall be specified with a minimum of 375 kg/m^3 and the specified D_{upper} shall not exceed 16 mm.

(4) Depending upon the D_{max} selected by the concrete producer, the minimum cement content for concrete used in diaphragm walls shall conform to Table D.2.

Table D.2 — Minimum cement content for concrete for diaphragm walls

| D_{max} mm | Minimum cement content kg/m^3 |
|------------------------|---|
| 32 | 350 |
| 22,4 | 380 |
| 16 | 400 |

(5) Concrete with $D_{\text{max}} = 32 \text{ mm}$ used in diaphragm walls shall conform to the following:

- sand content ($D \leq 4 \text{ mm}$) greater than 40 % by mass of the total aggregate;
- fines ($D \leq 0,125 \text{ mm}$) in the concrete mix (including cement and other fine materials) between 400 kg/m^3 and 550 kg/m^3 .

D.3.3 Water/cement ratio

(1) The specified maximum water-cement ratio shall not be greater than

- that given in the provisions valid in the place of use for resisting the specified exposure classes; and
- 0,60;

whichever is the lower value.

D.3.4 Fresh concrete

(1) Except for semi-dry concrete, the consistence shall be specified as either a target flow, target slump or target slump-flow. Target values for flow diameter and slump to be specified are given in Table D.3.

NOTE For further information see Annex L, line 23.

Table D.3 — Target values of consistence for fresh concrete in different conditions

| Flow diameter in accordance with EN 12350-5 mm | Slump in accordance with EN 12350-2 mm | Typical conditions of use (examples) |
|---|---|---|
| 500 | 150 | — concrete placed in dry conditions |
| 560 | 180 | — concrete placed by pumping or — by tremie pipe in submerged conditions under water |
| 600 | 200 | — concrete placed by tremie pipe in submerged conditions under a support fluid. |

(2) Provisions valid in the place of use may set up target values deviating from Table D.3, e.g. to ensure that a high density mix is provided with the mix design of the concrete fulfilling the requirements related to exposure classes.

(3) The maximum tolerances for target values of consistence for flow and slump ≥ 100 mm for concrete used in special geotechnical works shall be ± 30 mm.

(4) Where relevant, consistence after a given period of time after mixing should be specified.

Annex E (informative)

Recommendation for the use of aggregates

E.1 General

(1) This annex provides recommendations for the use of:

- natural normal-weight aggregates, heavy-weight aggregates and air-cooled blast furnace slag conforming to EN 12620;
- coarse recycled aggregates conforming to EN 12620;
- lightweight aggregates conforming to prEN 13055.

E.2 Natural normal-weight and heavy-weight aggregates and air-cooled blast furnace slag

(1) Table E.1 provides recommendations for the properties of natural normal-weight and heavy-weight aggregates and air-cooled blast furnace slag.

Table E.1 — Recommendations for natural normal-weight and heavy-weight aggregates and for air-cooled blast furnace slag

| Property ^a | Clause in EN 12620:2002+A1:2008 | Category according to EN 12620 ^a |
|---|---------------------------------|---|
| Fines content | 4.6 | Category or value to be declared |
| Flakiness Index | 4.4 | $\leq FI_{50}$ or $\leq SI_{55}$ |
| Shell content ^b | 4.5 | SC_{10} |
| Resistance to fragmentation | 5.2 | $\leq LA_{50}$ or $\leq SZ_{32}$ |
| Oven dried particle density ρ_{rd} | 5.5 | Value to be declared |
| Water absorption | 5.5 | Value to be declared |
| Acid-soluble sulfate | 6.3.1 | Natural aggregates: $\leq AS_{0,8}$ Air-cooled blast furnace slag: $\leq AS_{1,0}$ |
| Total sulfur content | 6.3.2 | Natural aggregates: ≤ 1 % by mass Air-cooled blast furnace slag: ≤ 2 % by mass |
| Water-soluble chloride ion content | 6.2 | Value to be declared |

^a Category NR (no requirement) may apply to other properties not stated in this table for which a category NR can be declared according to EN 12620.

^b Only relevant for aggregate from marine origin.

E.3 Recommendation for the use of coarse recycled aggregates

(1) This clause provides recommendations for the use of coarse recycled aggregates with $d \geq 4$ mm.

(2) Table E.2 gives limits for the replacement of natural normal-weight coarse aggregates by coarse recycled aggregates in relation to exposure classes. Table E.2 is valid for coarse recycled aggregates conforming to EN 12620 and the categories stated in Table E.3.

Table E.2 — Maximum percentage of replacement of coarse aggregates (% by mass)

| Recycled aggregate type | Exposure classes | | | |
|---|------------------|----------|-------------------------|---|
| | X0 | XC1, XC2 | XC3, XC4, XF1, XA1, XD1 | All other exposure classes ^a |
| Type A: (Rc_{90} , Rcu_{95} , Rb_{10-} , Ra_{1-} , FL_{2-} , XRg_{1-}) | 50 % | 30 % | 30 % | 0 % |
| Type B ^b : (Rc_{50} , Rcu_{70} , Rb_{30-} , Ra_{5-} , FL_{2-} , XRg_{2-}) | 50 % | 20 % | 0 % | 0 % |
| ^a Type A recycled aggregates from a known source may be used in exposure classes to which the original concrete was designed with a maximum percentage of replacement of 30 %. ^b Type B recycled aggregates should not be used in concrete with compressive strength classes > C30/37. | | | | |

NOTE For the risk of alkali-silica reaction with recycled aggregates, see EN 12620:2002+A1:2008, G.3.2.

Table E.3 — Recommendations for coarse recycled aggregates according to EN 12620

| Property ^a | Clause in EN 12620:2002+A1:2008 | Type | Category according to EN 12620 |
|---|---------------------------------|-------|--|
| Fines content | 4.6 | A + B | Category or value to be declared |
| Flakiness Index | 4.4 | A + B | $\leq FI_{50}$ or $\leq SI_{55}$ |
| Resistance to fragmentation | 5.2 | A + B | $\leq LA_{50}$ or $\leq SZ_{32}$ |
| Oven dried particle density ρ_{rd} | 5.5 | A | $\geq 2\,100$ kg/m ³ |
| | | B | $\geq 1\,700$ kg/m ³ |
| Water absorption | 5.5 | A + B | Value to be declared |
| Constituents ^b | 5.8 | A | Rc_{90} , Rcu_{95} , Rb_{10-} , Ra_{1-} , FL_{2-} , XRg_{1-} |
| | | B | Rc_{50} , Rcu_{70} , Rb_{30-} , Ra_{5-} , FL_{2-} , XRg_{2-} |
| Water soluble sulfate content | 6.3.3 | A + B | $SS_{0,2}$ |
| Acid-soluble chloride ion content | 6.2 | A + B | Value to be declared |
| Influence on the initial setting time | 6.4.1 | A + B | $\leq A_{40}$ |
| ^a Category NR (no requirements) applies for all other properties not stated in this table for which a category NR can be declared according to EN 12620. ^b For special applications requiring high quality surface finish the constituent FL should be limited to category $FL_{0,2-}$. | | | |

E.4 Recommendation for the use of lightweight aggregates

(1) Table E.4 provides recommendations for the properties of lightweight aggregates.

Table E.4 — Recommendations for lightweight aggregates according to prEN 13055

| Property | Requirement |
|---|---------------------------|
| Particle density | Value to be declared |
| Grading | Grading to be declared |
| Fines content | Value to be declared |
| Water absorption (5', 60' and 24h) | Value to be declared |
| Bulk crushing resistance | Value to be declared |
| Water-soluble chloride ion content | Value to be declared |
| Acid-soluble sulfate | ≤ 0,8 % by mass |
| Total sulfur content | ≤ 0,8 % by mass |
| Organic contaminants ^a | Requirement of prEN 13055 |
| ^a Only for natural lightweight aggregates. | |

NOTE For the risk of alkali-silica reaction with lightweight aggregates, see prEN 13055.

Annex F (informative)

Recommendation for limiting values of concrete composition

- (1) This annex provides recommendations for the choice of the limiting values of concrete composition and properties in relation to exposure classes according to 5.3.2.
- (2) The values in Table F.1 are based on the assumption of an intended design working life of the structure of 50 years.
- (3) The values in Table F.1 refer to the use of common cements conforming to EN 197-1, for which suitability for use in a considered exposure class has been established in provisions valid in the place of use, and normal weight aggregates with D_{\max} in the range of 20 mm to 32 mm.
- (4) The minimum strength classes were derived from the relationship between water/cement ratio and the strength class of concrete made with cement of strength class 32,5.
- (5) The limiting values for the maximum water/cement ratio and the minimum cement content apply in all cases, whilst the requirements for concrete strength class may be additionally specified.

Table F.1 — Recommended limiting values for composition and properties of concrete

| Exposure classes | | | | | | | | | | | | | | | | | | | | | |
|--|---|--------|--------|--------|--------|----------------------------|--------|--------|------------------------------------|--------|--|--------------------|------------------|------------------|--------|---------------------------------------|--------|--|----------------------------------|--|--|
| No risk of corrosion or attack | Carbonation-induced corrosion | | | | | Chloride-induced corrosion | | | | | | Freeze/thaw attack | | | | | | | Aggressive chemical environments | | |
| | | | | | | Sea water | | | Chloride other than from sea water | | | | | | | | | | | | |
| X0 | XC 1 | XC 2 | XC 3 | XC 4 | XS 1 | XS 2 | XS 3 | XD 1 | XD 2 | XD 3 | XF 1 | XF 2 | XF 3 | XF 4 | XA 1 | XA 2 | XA 3 | | | | |
| Maximum w/c^c | – | 0,65 | 0,60 | 0,55 | 0,50 | 0,50 | 0,45 | 0,45 | 0,55 | 0,45 | 0,55 | 0,55 | 0,50 | 0,45 | 0,55 | 0,50 | 0,45 | | | | |
| Minimum strength class | C12/15 | C20/25 | C25/30 | C30/37 | C30/37 | C30/37 | C35/45 | C35/45 | C30/37 | C30/37 | C30/37 | C25/30 | C30/37 | C30/37 | C30/37 | C30/37 | C35/45 | | | | |
| Minimum cement content ^c (kg/m ³) | – | 260 | 280 | 280 | 300 | 300 | 320 | 340 | 300 | 300 | 300 | 300 | 320 | 340 | 300 | 320 | 360 | | | | |
| Minimum air content (%) | – | – | – | – | – | – | – | – | – | – | – | 4,0 ^a | 4,0 ^a | 4,0 ^a | – | – | – | | | | |
| Other requirements | – | – | – | – | – | – | – | – | – | – | Aggregate in accordance with EN 12620 with sufficient freeze/thaw resistance | | | | – | Sulfate-resisting cement ^b | | | | | |
| ^a | Where the concrete is not air entrained, the performance of concrete should be tested according to an appropriate test method in comparison with a concrete for which freeze/thaw resistance for the relevant exposure class is proven. | | | | | | | | | | | | | | | | | | | | |
| ^b | Where sulfate in the environment leads to exposure classes XA2 and XA3, it is essential to use sulfate-resisting cement conforming to EN 197-1 or complementary national standards. | | | | | | | | | | | | | | | | | | | | |
| ^c | Where the k -value concept is applied the maximum w/c ratio and the minimum cement content are modified in accordance with 5.2.5.2. | | | | | | | | | | | | | | | | | | | | |

Annex G (informative)

Guidelines for self-compacting concrete requirements in the fresh state

G.1 General

(1) Specific requirements for self-compacting concrete in the fresh state depend on the type of application, and especially on:

- confinement conditions related to the concrete element geometry, and the type, location and number of inserts (reinforcement density, spacing, cover and any recesses etc.);
- placing equipment (pump, truck-mixer, skip);
- placing procedure (distance between delivery points in the concrete sections);
- finishing method.

(2) The classification system according to Clause 4 provides for an appropriate specification of SCC to cover these requirements, which are characterised by four key test parameters:

- slump-flow SF;
- viscosity VS or VF;
- passing ability PL or PJ;
- segregation resistance SR.

(3) Self-compacting concrete characteristics that are appropriate for a given application should be selected from these four parameters and then specified by class or target value according to 5.4.1.

(4) In the case of precast concrete and site-mixed concrete, it is usual to directly demonstrate the quality of final concrete in the product. For ready-mixed concrete, parameters and classes should be carefully selected, controlled and justified on the basis of contractor and concrete producer experience or by specific trials. It is therefore important that the concrete specifier and concrete producer discuss and define clearly those parameters before starting concreting.

(5) Slump-flow will normally be specified.

(6) If there is little or no reinforcement, there may be no need to specify passing ability as a requirement, see G.2.3. Viscosity of self compacting concrete may be important where good surface finish is required or reinforcement is very dense, see G.2.2. Stability becomes increasingly important with higher fluidity and lower viscosity self-compacting concrete.

(7) The required consistence retention time will depend on the transportation and placing time as well as on the concrete temperature. This should be determined and specified, and the self-compacting concrete should maintain its fresh properties during this period.

(8) Self-compacting concrete should, if possible be placed in one continuous pour, so delivery rates should be matched to placing rate and also be agreed with the producer in order to avoid interruptions to placing due to delays in delivery or in placing after the concrete reaches site.

NOTE For further guidance on SCC, see [2].

G.2 Recommendations on classification of self-compacting concrete

G.2.1 Consistence

(1) The slump-flow value relates to the consistence and it will normally be specified.

G.2.2 Viscosity

(1) The flow of self-compacting concrete with low viscosity will initially be very rapid, and then stop. Self-compacting concrete with high viscosity may continue to flow over an extended time. Viscosity of self-compacting concrete can be assessed by measuring either the t_{500} (in the slump-flow test) or the t_v (in the V-funnel test).

(2) It may be helpful to measure the t_{500} time while doing the slump-flow test as a way of confirming uniformity of the self-compacting concrete from batch to batch.

G.2.3 Passing ability

(1) Passing ability relates to the capacity of the fresh mix to flow without loss of uniformity or causing blocking through confined spaces and narrow openings such as areas of congested reinforcement. In defining the passing ability, it is necessary to consider the geometry of the reinforcement.

(2) The defining dimension is the smallest gap through which SCC has to continuously flow through to fill the formwork ("flowing gap").

(3) For complex structures with a flowing gap less than 60 mm, specific mock-up trials may be necessary.

G.2.4 Segregation resistance

(1) The segregation resistance describes the stability of the self-compacting concrete that is fundamental for its in situ homogeneity and quality.

(2) Self-compacting concrete can suffer from both dynamic segregation during placing and static segregation after placing, but before stiffening. Static segregation will be most detrimental in tall elements but even in thin slabs, it can lead to surface defects such as cracking or a weak surface.

(3) The segregation resistance test is not applicable to concrete containing fibres or lightweight aggregate.

(4) Further guidance on the production and other aspects of self-compacting concrete is given in [2].

Annex H (informative)

Rules of application for 8.2.1.3, Method C

H.1 Introduction

(1) Concrete production is based on the assumption that when the same quantities of constituents of the same type are batched and mixed, the concrete will have the same properties. Control charts use past production data to check if that assumption is valid by comparing what is actually achieved with what is expected. They detect where there has been a change in properties that requires corrective action(s).

(2) The following rules of application satisfy the requirements for Method C in 8.2.1.3 for an AOQL of not exceeding 5 %.

NOTE CEN/TR 16369 gives guidance on the use of control charts, the background of the suggested acceptance control charts and in particular it gives a range of other options for selecting Cusum V-mask parameters and target values that satisfy an AOQL not exceeding 5 %.

H.2 Control based on the cusum system

(1) A cusum control system based on ISO 7870-4 and having the following characteristics will satisfy 8.2.1.3, Method C:

- Where conformity is based on 28-day strengths, a system for predicting 28 day strength from earlier strength testing is recommended. These predicted strength values are then replaced by the actual 28 day strengths when these become available.

NOTE 1 If the early strength testing shows strengths in excess of those required at 28 days, testing at 28 days is not required.

- Where appropriate, concrete families may be used.
- Continual monitoring and plotting of three properties: mean strength, standard deviation and, where applicable, the correlation between the early strength and 28 day strength data. Conformity is based on mean strength only.
- Target mean strength set at a level $\geq (f_{ck} + 1,96 \sigma)$.
- Minimum estimated standard deviation of 3,0 N/mm².
- The V-mask for mean strength (for conformity/non-conformity) has only an upper limb with a decision interval of 9 σ and a gradient of 0,5 σ and a length of 35 results.
- The V-mask for warning lines has an upper and lower limb. Appropriate warning lines for mean strength and correlation are given by a decision interval of 8,1 σ and a gradient of $\sigma / 6$.

NOTE 2 Crossing such warning lines does not lead to non-conformity.

- Conformity/non-conformity is based on actual 28-day strength data and is assessed over the latest 35 test results, not exceeding 12 months.
- When the cusum plot for mean strength crosses the non-conformity line, non-conformity is declared on the assessed 35 test results, unless it can be shown that the non-conformity declaration is due to some specific low strength results in which case the non-conformity declaration can be limited to the period in which these low strength results occur.

(2) Where the actual mean strength is shown to be higher than the target mean strength or the actual standard deviation is lower than the current value, changes to the mix proportions are optional.

H.3 Control based on Shewhart charts with modified limits by variables

(1) ISO 7870-2 gives general information on Shewhart control charts and ISO 7870-3 gives general information on Shewhart control charts for acceptance control. Shewhart control charts with modified limit by variables are a specific application of these charts where the aim is to assess that the characteristic strength of the produced concrete is higher than a required value.

(2) A Shewhart control chart having the following characteristics will satisfy 8.2.1.3, Method C:

- where appropriate, concrete families may be used;
- continual monitoring and plotting of two properties: mean strength and standard deviation. Conformity is based on mean strength only;
- minimum estimated standard deviation of 3,0 N/mm²;
- non-conformity is declared when the average of n measured strength results is lower than a lower line L_1 situated at a given distance from f_{ck} with:

$$L_1 \geq f_{ck} + (q_n \sigma) \quad (\text{H.1})$$

where

q_n depends on n and on the AOQL chosen;

σ is an estimated standard deviation, controlled by the control chart for standard deviation.

In case $15 \leq n \leq 35$ and $q_n \geq 1,48$, the Shewhart charts will satisfy the requirements of 8.2.1.3.2, Method C.

- conformity/non-conformity is based on actual 28-day strength data and is assessed over the latest n test results obtained over a period not exceeding 12 months.

Annex J **(informative)**

Deviation to accommodate a notified Spanish Regulation

(1) In the mandatory Spanish Regulation (Instrucción de Hormigón Estructural (in English: Structural Concrete Code), approved 18 July 2008 by Royal Decree 1247/2008), there is the requirement for the consumer risk to be not greater than 50 % where the population in the assessment period has exactly 5 % of all possible results below the characteristic strength. Alteration of this national regulation is outside of the competence of CEN/CENELEC members. For the application of EN 206 in Spain, the national regulation remains valid and Spain is free to use higher coefficients in formulation presented in section 8.2.1.3.2 (method B).

Annex K (informative)

Concrete families

K.1 General

(1) This annex provides details on the use of concrete families as permitted in 8.2.1.1.

NOTE For further guidance, see CR 13901 and CEN/TR 16369.

K.2 Selection of the concrete family

(1) When selecting the family for production and conformity control, the producer needs to achieve control over all the family members. Where there is little experience of using the concrete family concept, the following is recommended for a family:

- cement of one type, strength class and source;
- demonstrably similar aggregates and type I additions;
- concretes with or without a water reducing/ plasticising admixture;
- full range of consistence classes;
- concretes with a limited range of strength classes.

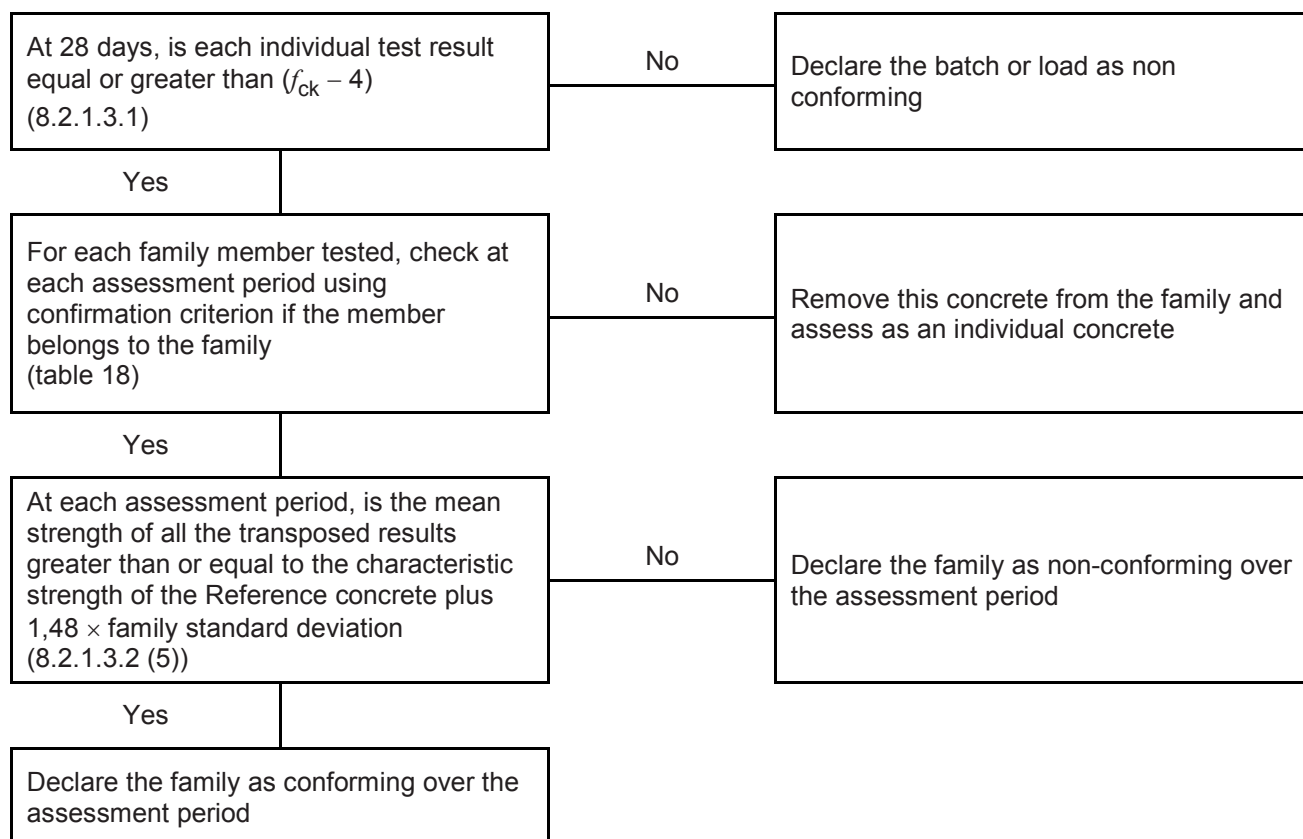
(2) Concretes containing a type II addition, i.e. a pozzolanic or latent hydraulic addition, should be put into a separate family.

(3) Concretes containing admixtures that may have an impact on compressive strength, e.g. high range water reducing/superplasticising, accelerators, retarding or air entraining admixture should be treated as individual concretes or separate families.

(4) To be demonstrably similar, aggregates should be from the same geological origin, be of the same type, e.g. crushed, and have a similar performance in concrete.

(5) Before using the family concept or extending the families given above, the relationships should be tested on previous production data to prove that they give adequate and effective production and conformity control.

K.3 Flow chart for the assessment of membership and conformity of a concrete family



Annex L (informative)

Further information regarding specific paragraphs

Regarding specific paragraphs in this standard, please note the following information:

| Line | Clause | Note |
|------|---------------|---|
| 1 | 4.2.1 (2) | The consistence should be specified by target values only in special cases. |
| 2 | 4.3.1 (1) | In special cases, intermediate strength levels between those in Tables 12 or 13 may be used. |
| 3 | 5.1.2 (2) | When using cements conforming to EN 14647 or EN 15743, transport vehicles for cement, silos and conveying systems should be emptied before the changeover to other cements and after the end of use. |
| 4 | 5.2.3.5 (1) | Precautions appropriate to the geological sources of the aggregates should be followed, taking into account long term experience with the particular combination of cement and aggregate. CEN/TR 16349 gives a framework for specifying requirements for minimising the risk of damaging alkali-silica reaction. |
| 5 | 5.2.5.1 (1) | The influence of additions on properties other than strength should be taken into account. |
| 6 | 5.2.5.1 (5) | The establishment of the suitability referred in (4) and (5) should result from provisions valid in the place of use of the concrete. |
| 7 | 5.2.5.2.4 (1) | A k -value of 0,6 for concrete containing cement types CEM I and CEM II/A conforming to EN 197-1 is recommended for ggbs conforming to EN 15167-1. The maximum amount of ggbs should meet the recommendation: $\text{ggbs/cement} \leq 1,0$ by mass. If a greater amount of ggbs is used, the excess should not be taken into account for the calculation of the $\text{water}/(\text{cement} + k \times \text{ggbs})$ ratio and the minimum cement content. |
| 8 | 5.2.6 (4) | If the compatibility test for air-entraining agent in combination with other admixtures has not been undertaken by the admixture supplier, it should be performed within the initial testing. |
| 9 | 5.2.7 (1) | This standard provides rules for the production of concrete with a specified quantity of fibres. Where specific design parameters are required, procedures for testing and documentation of conformity should be agreed. |
| 10 | 5.4.1 (1) | Due to the lack of sensitivity of the test methods beyond certain values of consistence, it is recommended to use the indicated tests for: <ul style="list-style-type: none"> — slump ≥ 10 mm and ≤ 210 mm; — degree of compactibility $\geq 1,04$ and $< 1,46$; — flow diameter > 340 mm and ≤ 620 mm; — slump flow diameter > 550 mm and ≤ 850 mm. |

- 11 5.4.2 (2) For fine lightweight aggregate, the test method and criteria should follow the provisions valid in the place of use of the concrete.
- 12 5.5.1.2 (5) Assessing the strength in the structure or structural component should be based on EN 13791.
- 13 6.2.3 (1) Before specifying the air content at delivery, the possible loss of air during pumping, placing, compacting etc. subsequent to the delivery should be taken into account by the specifier.
- 14 6.3.2 (1), d) The specified value of the target w/c ratio should be at least 0,02 less than any intended limiting value.
- 15 7.5 (4) If admixtures, pigments, fibres or water are added to the concrete in a truck mixer on site without approval/supervision of the producer's quality management personnel or is more than is permitted by the specification of concrete, the concrete batch or load should be recorded as "non-conforming" on the delivery ticket. The party who authorised this addition is responsible for the consequences and this party should be recorded on the delivery ticket.

- 16 8.2.1.3.2 (8) These limits are based on the following formula:

$$\sqrt{\frac{\chi_{0,025;n-1}^2}{(n-1)}} \sigma \leq s_n \leq \sqrt{\frac{\chi_{0,975;n-1}^2}{(n-1)}} \sigma \quad (4)$$

where $\chi_{\alpha;\nu}^2$ the α -fractile of a chi-square distribution with $\nu = n - 1$ degrees of freedom.

- 17 8.2.1.3.2 (10) As a control chart comprises successive sampling plans (with a known standard deviation), the operating-characteristic curve of the individual sampling plan may be established. The AOQ curve is then determined by multiplying each percentage of all possible results below the required characteristic strength in the production by the corresponding acceptance probability.
- 18 8.2.2.1 (1) Where flexural strength is specified, the same approach may be used.
- 19 9.7 (2) Batching tolerances for batches less than 1 m³ should be given in provisions valid in the place of use.
- 20 9.8 (3) In a truck mixer, the duration of re-mixing after the main mixing process should not be less than 1 min/m³ and not less than 5 min after adding the admixtures or fibres.
- 21 A.4 (1) If concreting on the site will be done under widely divergent temperature conditions, or if heat treatment is applied, the producer should be informed about this, so that he can consider the concerning effects on the properties of the concrete and the need for any additional tests.
- 22 A.4 (9) The proportions in Table E.2, based on experience, give concrete with normal deformation properties and testing is not normally needed. In special cases, e.g. long spanned beams, testing is required and the need for such testing should be agreed between producer and user.
- 23 D.3.4 (1) Concrete placed by pumping or in submerged conditions (flow diameter at least 560 mm or slump at least 180 mm) may be produced without the use of high range water reducing/super plasticising admixture.

Annex M (informative)

Guidance on provisions valid in the place of use

Provisions valid in the place of use are required or permitted in the following clauses of this standard:

| Clause | Title | Paragraph |
|-----------|--|---|
| 1 | Scope | paragraphs (5) and (6) |
| 4.1 | Exposure classes related to environmental actions | paragraphs (1) and (2) |
| 5.1.1 | General | paragraph (2) |
| 5.1.2 | Cement | paragraph (2) |
| 5.1.3 | Aggregates | paragraphs (1) and (2) |
| 5.1.5 | Admixtures | paragraph (2) |
| 5.2.1 | General | paragraphs (2) and (5) |
| 5.2.3.5 | Resistance to alkali-silica reaction | paragraph (1) |
| 5.2.5.1 | General | paragraph (2), (4) and (5) |
| 5.2.5.2.3 | <i>k</i> -value for silica fume of class 1 conforming to EN 13263-1 | paragraph (4) |
| 5.2.5.2.4 | <i>k</i> -value for ground granulated blastfurnace slag conforming to EN 15167-1 | paragraph (1) |
| 5.2.5.3 | Equivalent Concrete Performance Concept | paragraph (3) |
| 5.2.8 | Chloride content | Table 15, "Maximum chloride content of concrete", footnotes a and c |
| 5.3.2 | Limiting values for concrete composition | paragraphs (1) and (3) |
| 5.3.3 | Performance-related methods | paragraphs (1) |
| 5.4.2 | Cement content and water/cement ratio | paragraph (2) |
| 6.1 | General | paragraph (2) |
| 6.4 | Specification of standardized prescribed concrete | paragraph (2) |
| 7.2 | Information from the producer of the concrete to the user | paragraph (4) |
| 7.3 | Delivery ticket for ready-mixed concrete | paragraph (3) |
| 8.2.1.2 | Sampling and testing plan | Table 17, "Minimum rate of sampling for assessing conformity", footnote d |
| 8.2.1.3.2 | Criteria for mean results | paragraph (11) |
| 8.2.3.3 | Conformity criteria for properties other than strength | Table 21, "Conformity criteria for consistence, air content and homogeneity of fibre distribution of fresh concrete at the point of delivery", footnote c |
| 8.2.3.3 | Conformity criteria for properties other than strength | Table 23, "Tolerances for target values of consistence and viscosity", footnote a |
| 9.4 | Testing | paragraph (2) |
| 9.7 | Batching of constituents | paragraph (2) |
| 9.9 | Production control procedures | Table 28, "Equipment control", row 3, column 4 |

| | | |
|-------------|---|---|
| 10.2 | Assessment, surveillance and certification of production control" | paragraph (1) |
| Annex A.4 | Test conditions | paragraph (5) |
| Annex D.2.1 | Cement | paragraphs (1) and (3) |
| Annex D.3.3 | Water/cement ratio | paragraph (1) |
| Annex D.3.4 | Fresh concrete | paragraph (2) |
| Annex F | Recommendation for limiting values of concrete composition | paragraph (3) |
| Annex F | Recommendation for limiting values of concrete composition | Table F.1, "Recommended limiting values for composition and properties of concrete", footnote b |

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- [5] EN 12390-5, *Testing hardened concrete — Part 5: Flexural strength of test specimens*
- [6] EN 12390-8, *Testing hardened concrete — Part 8: Depth of penetration of water under pressure*
- [7] CEN/TS 12390-9, *Testing hardened concrete — Part 9: Freeze-thaw resistance — Scaling*
- [8] CEN/TS 12390-10, *Testing hardened concrete — Part 10: Determination of the relative carbonation resistance of concrete*
- [9] CEN/TS 12390-11, *Testing hardened concrete — Part 11: Determination of the chloride resistance of concrete, unidirectional diffusion*
- [10] EN 12504-1, *Testing concrete in structures — Part 1: Cored specimens — Taking, examining and testing in compression*
- [11] EN 12504-2, *Testing concrete in structures — Part 2: Non-destructive testing — Determination of rebound number*
- [12] EN 12504-4, *Testing concrete in structures — Part 4: Determination of ultrasonic pulse velocity*
- [13] EN 13369, *Common rules for precast concrete products*
- [14] EN 13670, *Execution of concrete structures*
- [15] EN 13791, *Assessment of in-situ compressive strength in structures and precast concrete components*
- [16] EN 13877-1, *Concrete pavements — Part 1 : Materials*
- [17] CR 13901, *The use of the concept of concrete families for the production and conformity control of concrete*
- [18] CR 13902, *Test methods for determining the water/cement ratio of fresh concrete*
- [19] EN 14487-1, *Sprayed concrete — Part 1: Definitions, specifications and conformity*
- [20] EN 14647, *Calcium aluminate cement — Composition, specifications and conformity criteria*
- [21] CEN/TR 15177, *Testing freeze-thaw resistance of concrete — Internal structural damage*
- [22] EN 15743, *Supersulfated cement — Composition, specifications and conformity criteria*

- [23] CEN/TR 16349, *Framework for a specification on the avoidance of a damaging Alkali-Silica Reaction (ASR) in concrete*
- [24] CEN/TR 16369, *Use of control charts in the production of concrete*
- [25] CEN/TR 16563, *Principles of the equivalent durability procedure*
- [26] CEN/TR 16639, *Use of k -value concept, equivalent concrete performance concept and equivalent performance of combinations concept*
- [27] EN ISO 9001, *Quality management systems — Requirements (ISO 9001)*
- [28] ISO 2859-1:1999, *Sampling procedures for inspection by attributes — Part 1: Sampling schemes indexed by acceptance quality limit (AQL) for lot-by-lot inspection*
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- [31] ISO 7870-3, *Control charts — Part 3: Acceptance control charts*
- [32] ISO 7870-4, *Control charts — Part 4: Cumulative sum charts*
- [33] ISO 16204, *Durability — Service life design of concrete structures*
- [34] DIN 4030-2, *Assessment of water, soil and gases for their aggressiveness to concrete — Part 2: Sampling and analysis of water and soil samples*

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